



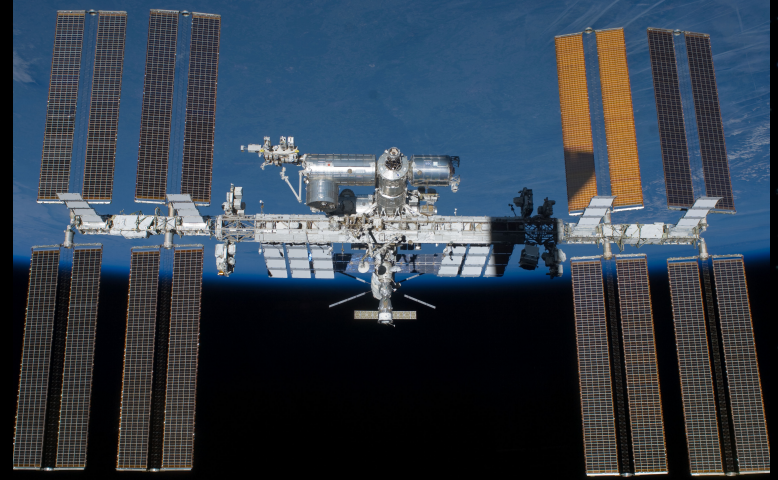
NASA Glenn's Role in Supporting Regional Economic Development

Eric Clark
Manager, Midwestern RED Initiative
NASA's Glenn Research Center
Cleveland, Ohio

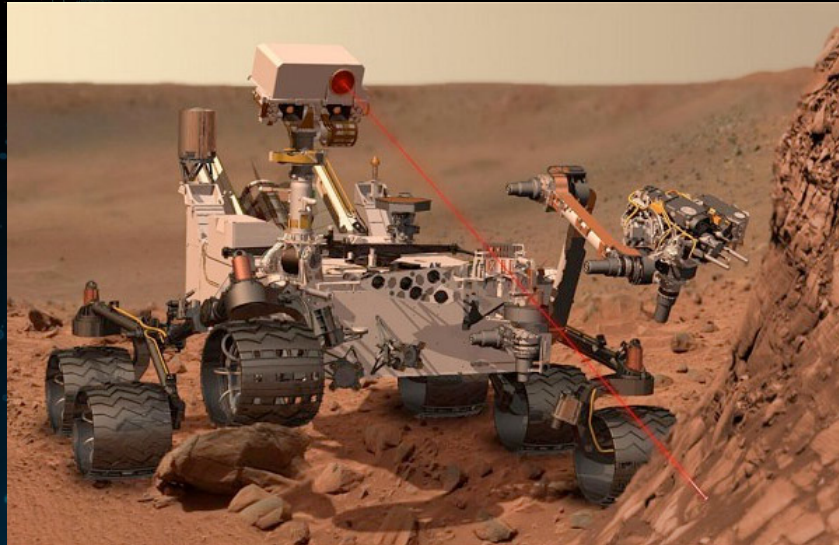
NASA is known for...



Space Shuttle



International Space Station



Mars Rover Curiosity

Opening the Gates of GRC!



*Research and technology **for the benefit of all***

Regional Economic Development (RED) Initiative (Strategic Regional Partnerships for Technology)

Purpose:

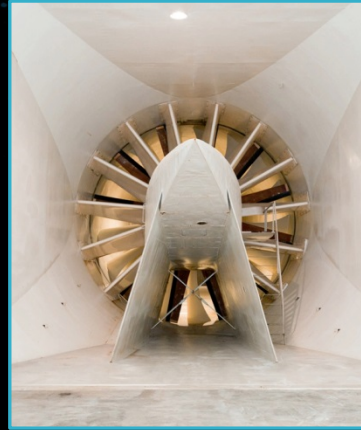
- Through regional partnerships with external public and private sector organizations, utilize NASA capabilities (subject matter experts, technologies, facilities) to support collaborations leading to regional economic development by the private sector in business sectors of critical importance to the region of interest.
- Regional economic development success is measured by impact of NASA collaborations on private sector outcomes of
 - Jobs created/retained
 - Increased revenue from improved/new product offerings
 - Funding (public/private) captured
- Metrics and outcomes for RED are measured using nationally accepted NIST Manufacturing Extension Partnership (MEP) Approach.

NASA's Key Products & Service Offerings to Non NASA Community

Intellectual
Property



Facilities Test (FT)
Services



Research, Development,
Test & Evaluation
(RDT&E) Services

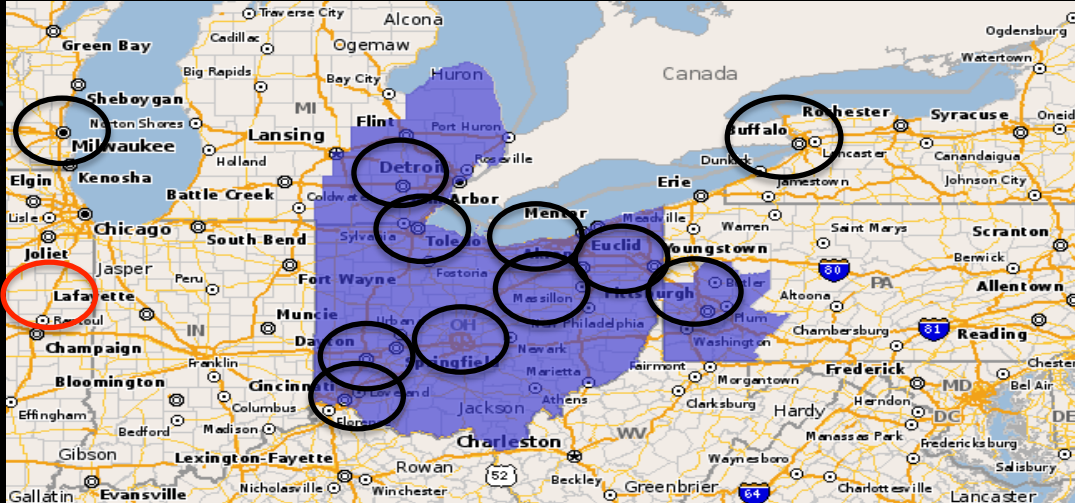


Subject Matter Expert
(SME) Services



GRC Is Actively reaching Out to Midwestern Region

The “Mini Midwest”



The Obama Administration's Strong Cities, Strong Communities Initiative (SC²)

Strengthening neighborhoods, towns, cities, and regions around the country by enhancing the capacity of local governments to develop and execute their economic vision and strategies through public/private partnerships

Success of Cleveland Adopt a City I,II

(Through December 2014)

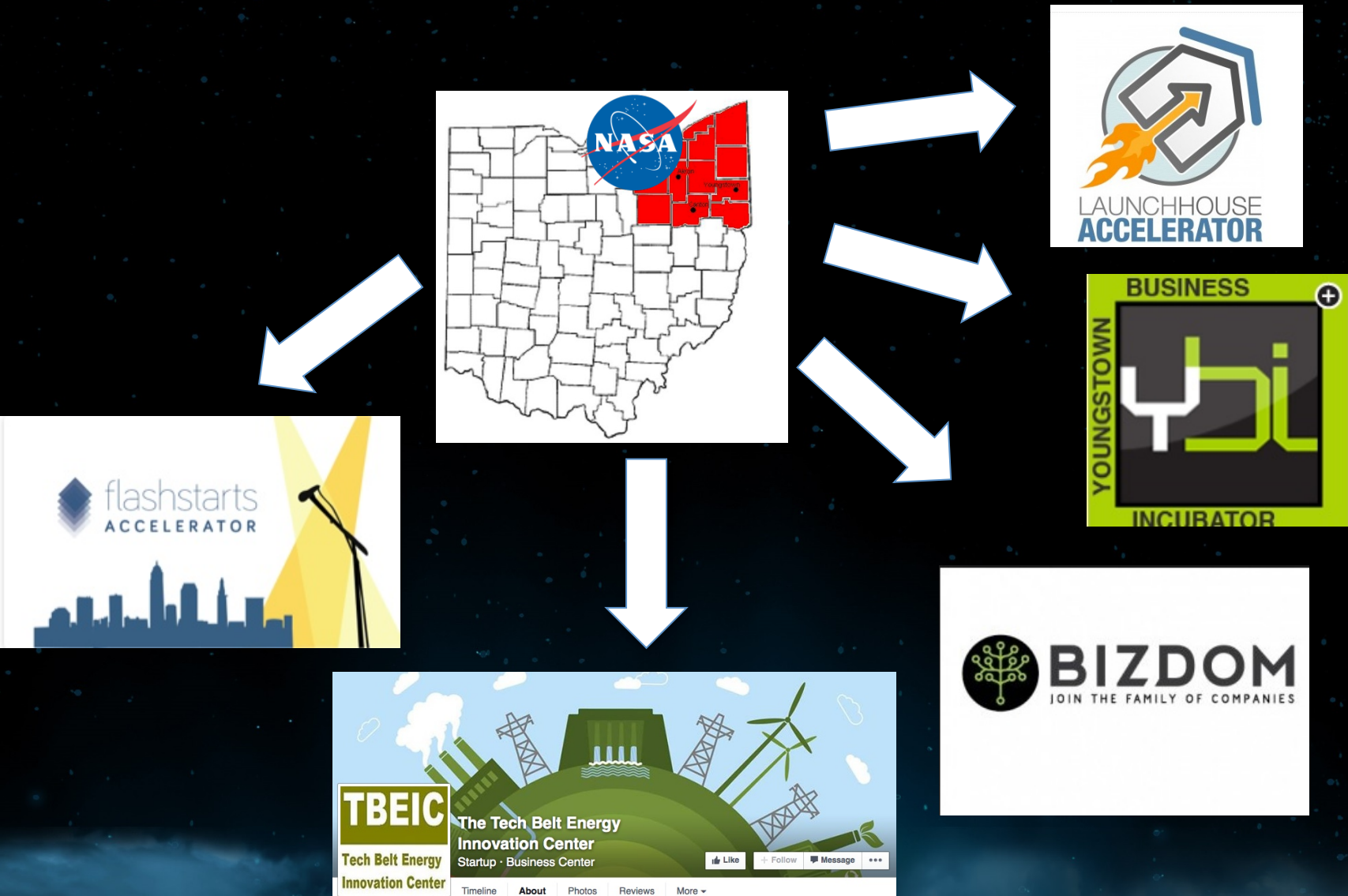
Company Participants

- | | |
|---------------------------------|----------------|
| -Bioinvision | -AlSher APM |
| -Gotta Grove Records | -MACE Security |
| -Megajoule | -Megajoule |
| -Morrison Products | -Mesocoat |
| -Pile Dynamics | -Skysun |
| -Sensor Development Corporation | -Sterionics |
| -Vadxx Energy | |
| -Zuga Medical | |

Economic Outcomes (As of December 2014)

Number of Jobs Created	19
Number of Jobs Retained	47
Number of Units Sold	301,831
Number of New Customers	27
Revenue Generated	\$2,714,500
Private Dollars Invested in Projects	\$33,839,822
Cost savings Realized as a Result of Projects	\$830,000

Partnering with Members of JumpStart Entrepreneurial Network



How Do I Engage with NASA Glenn?

Eric Clark

Manager, Midwest Regional Economic Development

Eric.b.clark@nasa.gov

216-433-3926

Regional Economic Development Website (coming soon)

<http://www.grc.nasa.gov/RegEconDev/>



TECHNOLOGY TRANSFER PROGRAM

BRINGING NASA TECHNOLOGY DOWN TO EARTH

Partnering with NASA Glenn to Access Our Capabilities Thru Space Act Agreements

Robert A. Kistemaker
Space Act Agreements Manager
May 24, 2016

Ways that you can work with Glenn ...

Intellectual Property
Evaluation License
Commercial License
QuickLaunch License
Software Usage
Agreement



Research,
Development, Test &
Evaluation (RDT&E)
Services
Reimbursable Space
Act Agreement



Facilities Test (FT)
Services
Reimbursable Space
Act Agreement



Subject Matter Expert
(SME) Services
Reimbursable Space
Act Agreement

Space Act Agreements – General Parameters I

The Space Act Agreement enables companies to work with NASA technical experts and use our research and testing facilities.

Primary mechanism used by NASA to partner with external parties. Can be reimbursable or non-reimbursable.

Proposed activity must be consistent with NASA missions and show need for our unique capabilities and technologies.

NASA may not provide goods or services that are attainable from the private sector.

Appropriate for all types of partners (small, medium, or large businesses, universities, non-profits, etc.)

Space Act Agreements – General Parameters II

How is Intellectual Property developed under a Space Act Agreement handled?

Intellectual property and data rights are defined upfront.

Background data which the Partner marks and supplies to NASA for the work to proceed is protected forever.

Data developed by Partner under the agreement will be protected by NASA and used for government purposes only.

Data developed by NASA under the agreement will be protected for a maximum of five years after the data is developed.

Fully Reimbursable Space Act Agreement

The fully reimbursable Space Act Agreement provides for full payment to NASA for goods and services provided.

Partner pays full cost of the effort upfront before work begins whenever NASA operates with non-appropriated funds.

A jointly-developed, specifically-defined statement of work (SOW) is required including milestones.

Work undertaken by NASA for Partner can only be done on a non-interference basis aside from our mission work.

Inventions resulting from work under a Space Act Agreement remain with the inventing party.

Non-Reimbursable Space Act Agreement

The non-reimbursable Space Act Agreement can occur where results of the activity are of interest to both NASA and Partner, as part of a collaborative effort.

Each party pays their own costs. Results must be shared by the parties. Results are to be published widely and without restriction.

A current NASA program must sponsor the proposed work and absorb NASA's share of the costs.

Requires justification that NASA's contribution of goods or services is equivalent to cost or effort of Partner.

Inventions resulting from work under a Space Act Agreement remain with the inventing party.

Space Act Agreement – Process for Enactment

The process of enacting a Space Act Agreement requires that NASA has the availability to engage Partner's needs.

Identify your technical need. Contact NASA researcher or specialist.

NASA determines legal instrument, program sponsor & provides cost estimate to Partner or justifies waiver of cost to NASA mgmt.

Researcher seeks internal approvals thru center New Business Council. Parties jointly develop SOW, milestones, schedule, etc.

Agreement is negotiated, drafted, reviewed and finalized between the parties. Start to finish lead time is about 10 to 12 weeks.

**Many of Glenn's patents
available for licensing
can be found at
<http://technology.nasa.gov/>
Glenn has licensing
options and the
flexibility to fit any need.**

Evaluation License - *Provides companies with time to explore the technology's potential before securing a commercial license. Try before you buy!*

Commercial License - *Individually negotiated with the prospective licensee.*

QuickLaunch License – *A selected portfolio of technologies with a set initial fee, annual royalty, and standard terms.*

Startup License - *A new NASA initiative for companies created for the sole purpose of commercializing a NASA technology.*

Software Usage Agreements

*NASA software is available for use by industry
See our Software Catalog*



There are multiple release categories for software (Govt-Use Only, U.S. Release Only, Open Source).

Access NASA software via the software catalog: <https://software.nasa.gov>

Requests can be handled entirely electronically online.

Available to all types of entities (business, government, academic) for no fee.



Key Takeaways....



Visit our website to view available technologies:

<http://technology.grc.nasa.gov/>

Access NASA software via the software catalog: <https://software.nasa.gov/>



Discover state-of-the-art facilities that can accelerate your R&D.

<https://facilities.grc.nasa.gov/using.html>



Contact GRC's Technology Transfer Office to discuss the right partnering option for your company. Email: ttp@grc.nasa.gov

OR Phone: **216-433-3484**



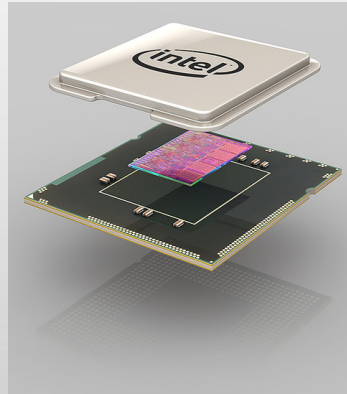
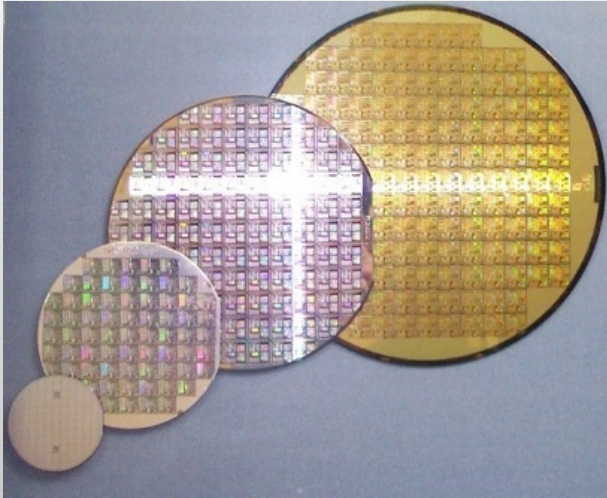
TECHNOLOGY TRANSFER PROGRAM

BRINGING NASA TECHNOLOGY DOWN TO EARTH

Partnership Opportunity: Prototyping of Extreme Environment Durable SiC Integrated Circuits

Dr. Philip G. Neudeck
May 23, 2016

Impact of Silicon Semiconductor Technology on Daily Life



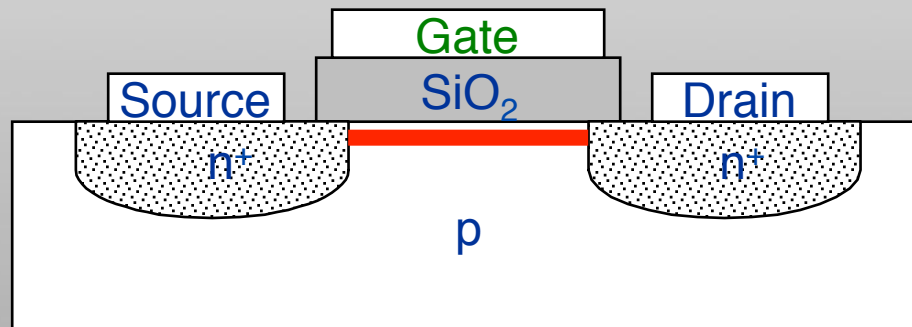
Semiconductor Transistor: The Foundation of Modern Electronics

Transistors enable smaller electrical signals to control larger electrical signals.

- Can function as ON/OFF “power switch” (power conversion).
- Can function as “Amplifier” of small signals (audio, communications).
- Can function as “Logic” decision making (computers, controllers).

Example: Metal Oxide Semiconductor Field Effect Transistor (MOSFET)

Electrical voltage at **Gate** controls **Drain-to-Source electrical current**.



Cross-sectional depiction
of silicon n-channel MOSFET

99% of semiconductor electronic transistors are silicon MOSFETs, with designs specifically optimized for each application.

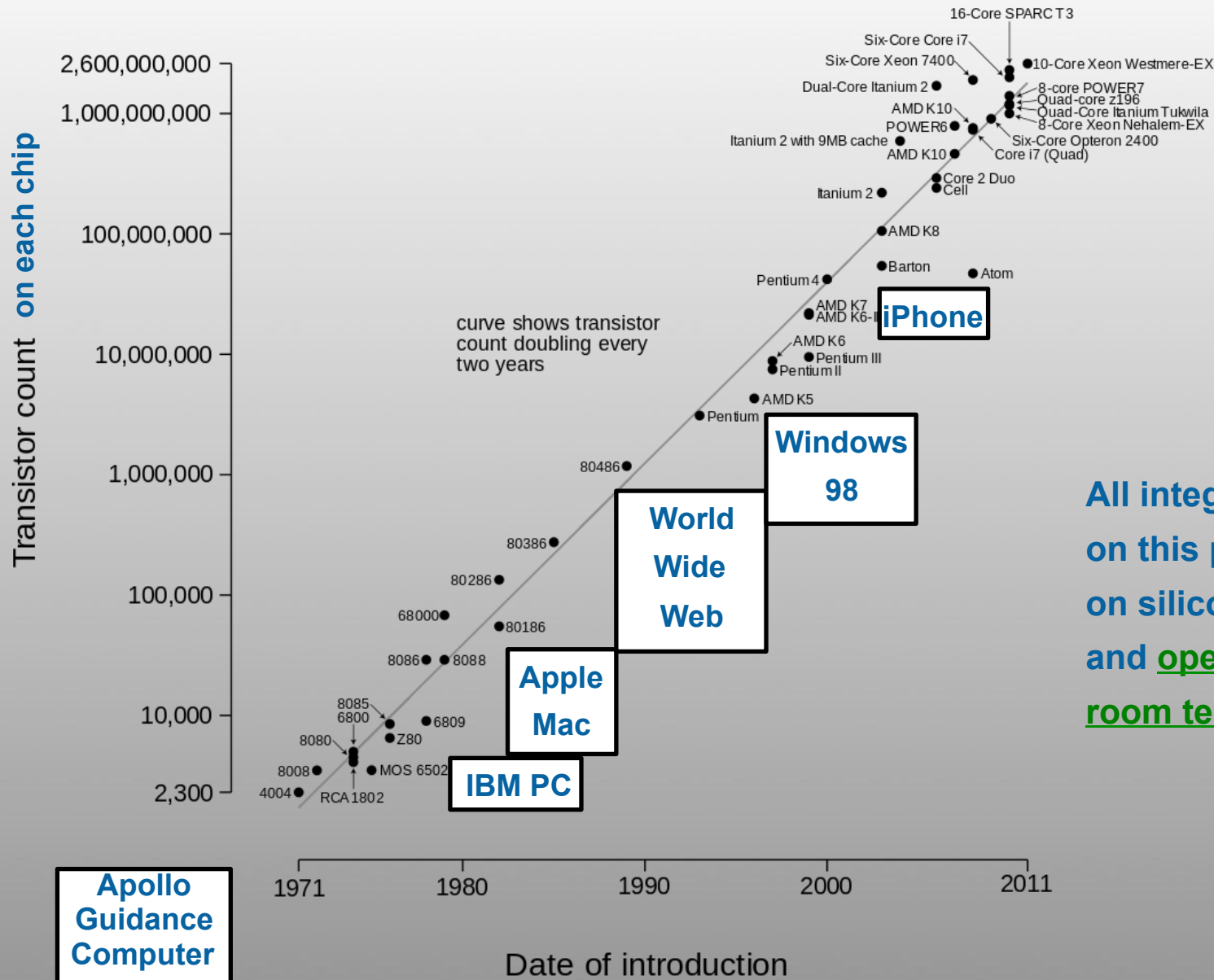
- Power ranges from 0.000000001 Watts to 100,000 Watts.

Microprocessor Transistor Counts 1971-2011 & Moore's Law

(Graph By Wgsimon - Own work, CC BY-SA 3.0, <https://commons.wikimedia.org/w/index.php?curid=5161625>)

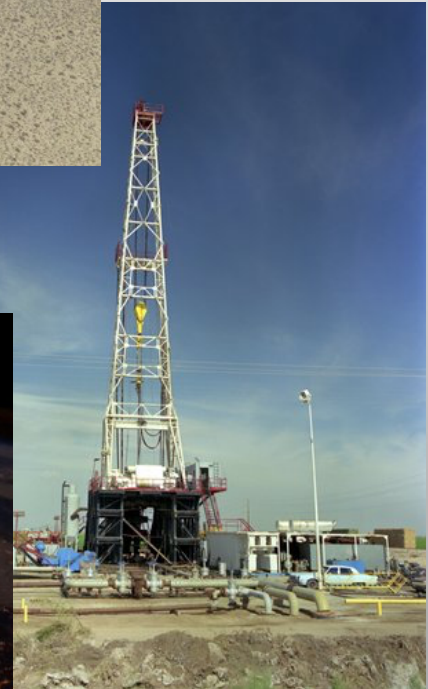
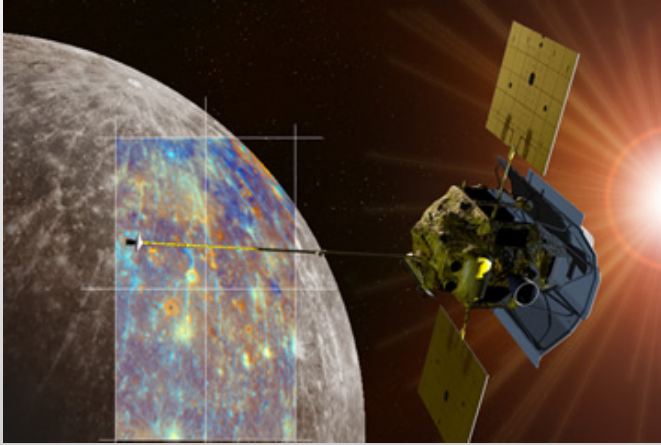


TECHNOLOGY
TRANSFER
PROGRAM



All integrated circuits
on this plot are based
on silicon transistors
and operate at
room temperature.

Applications Desiring Semiconductor Electronics Functionality at Higher Temperature



IMAPS International Conference and Exhibition on *High Temperature Electronics* (HiTEC 2016)

May 10-12, 2016
Albuquerque Marriott Pyramid North
Albuquerque, New Mexico, USA

Premier Sponsors:



PROGRAM OVERVIEW

MONDAY:

Pre-Conference Short Course on:
High Temperature Electronics
PDC Instructor: Randall Kirschman, Consultant



TUESDAY:

Plenary Session
TP1: SILICON
TP2: MATERIALS
Exhibit Reception



WEDNESDAY:

WA1: POWER
WA2: DIE ATTACH
WP1: POWER 2
WP2: MATERIALS ASSEMBLY
Complimentary Shuttle To Old Town

THURSDAY:

THA1: WIDE BANDGAP (SiC & GaN)
THA2: CAPACITORS & FILTERS

Organizing Committee:

Wayne Johnson, Tennessee Tech University
johnson@tntech.edu

Colin Johnston, Oxford University
colin.johnston@materials.ox.ac.uk

Susan L. Heidger, Air Force Research Laboratory
Susan.Heidger@kirtland.af.mil

F. Patrick McCluskey, University of Maryland
mcclupa@calce.umd.edu

Randy Normann, Perma Works, LLC
randy@permaworks.com



High Temperature Semiconductor Electronics Technologies



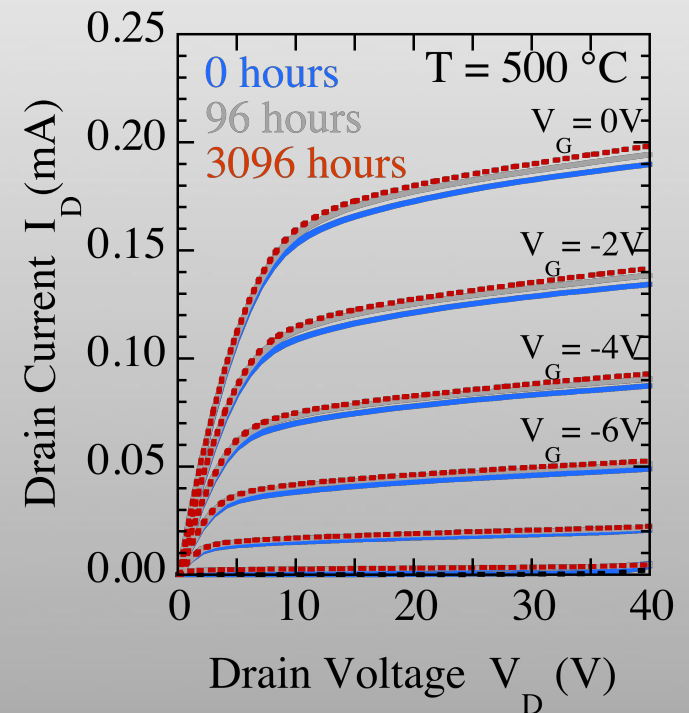
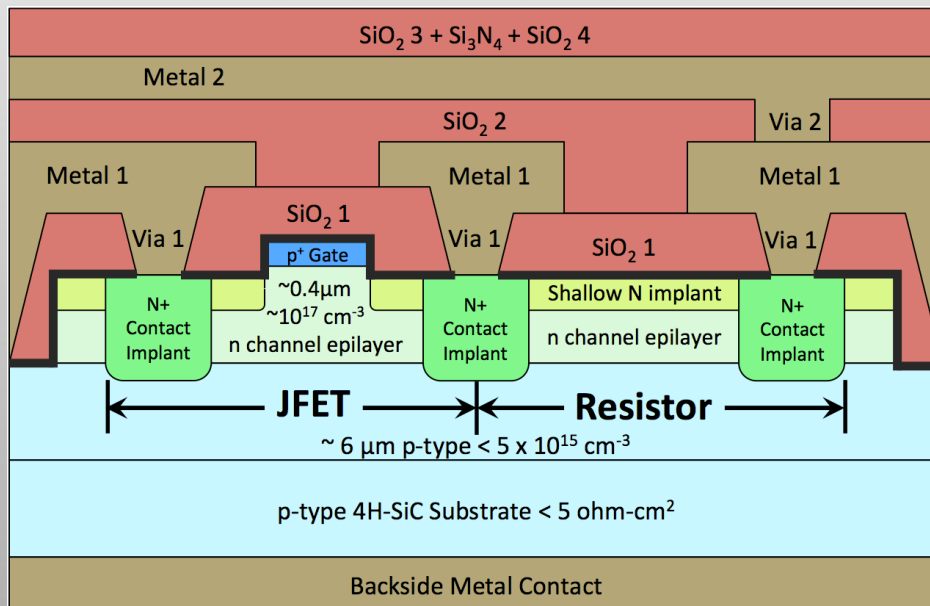
For $T < 150\text{ }^{\circ}\text{C}$, bulk silicon MOSFET (CMOS) is basic building block of almost all ($> 95\%$) integrated circuits in use today (computers, phones, etc.).

For $T < 300\text{ }^{\circ}\text{C}$, well-developed Silicon-On-Insulator (SOI) VLSI ICs available for low-power logic and signal processing solutions.

When temperature exceeds SOI limits ($\sim 300\text{ }^{\circ}\text{C}$), the semiconductor material must change to **Silicon Carbide (SiC)**.

Most applications require long-term circuit operation.

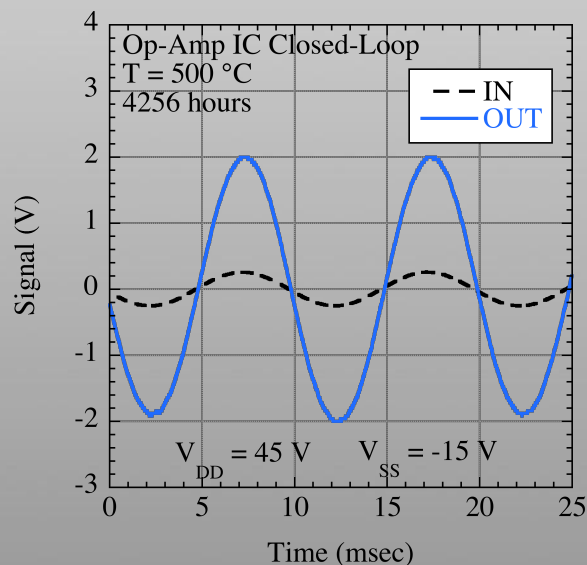
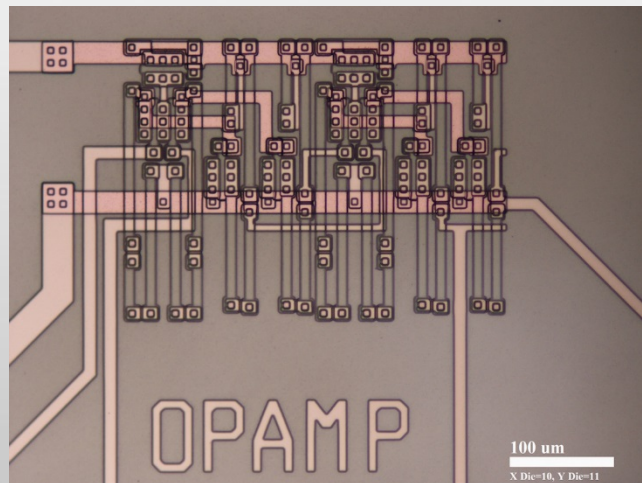
SiC n-JFETs and n-resistors offer the highest durability and stability for long-term circuit operation at $T \geq 500^\circ\text{C}$.



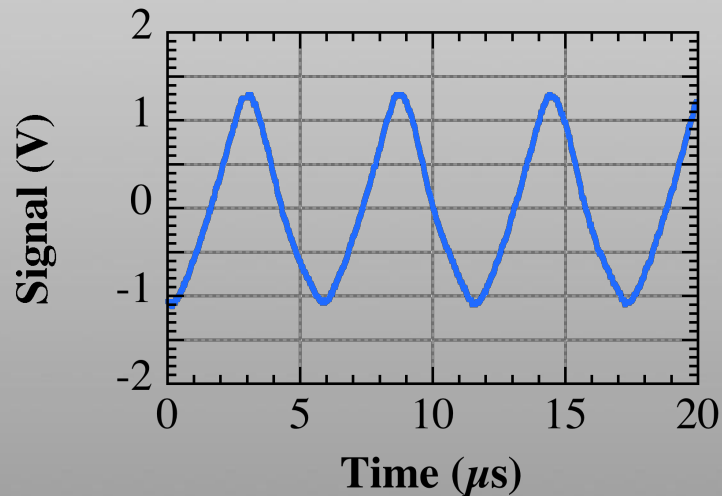
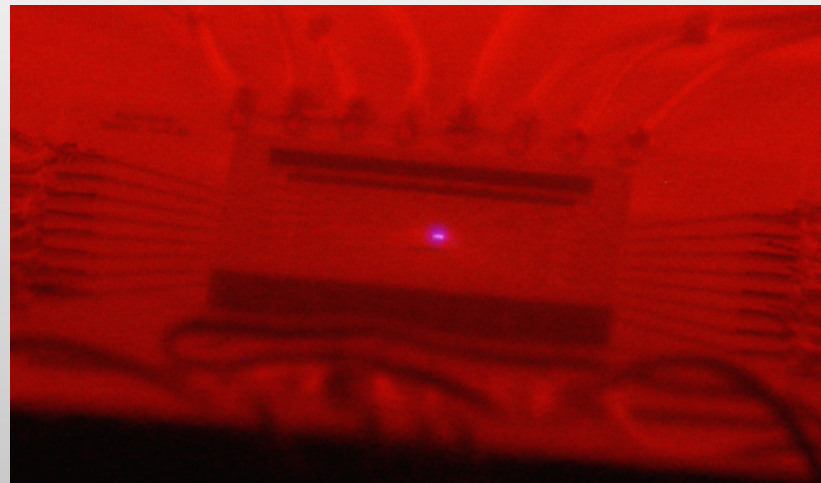
Other device structures and materials have yet to demonstrate 1000+ hours of 500°C stable electrical operation.

NASA Glenn Technology Advancement: 500 °C Durable SiC Integrated Circuits

6-Month 500 °C Op-Amp IC

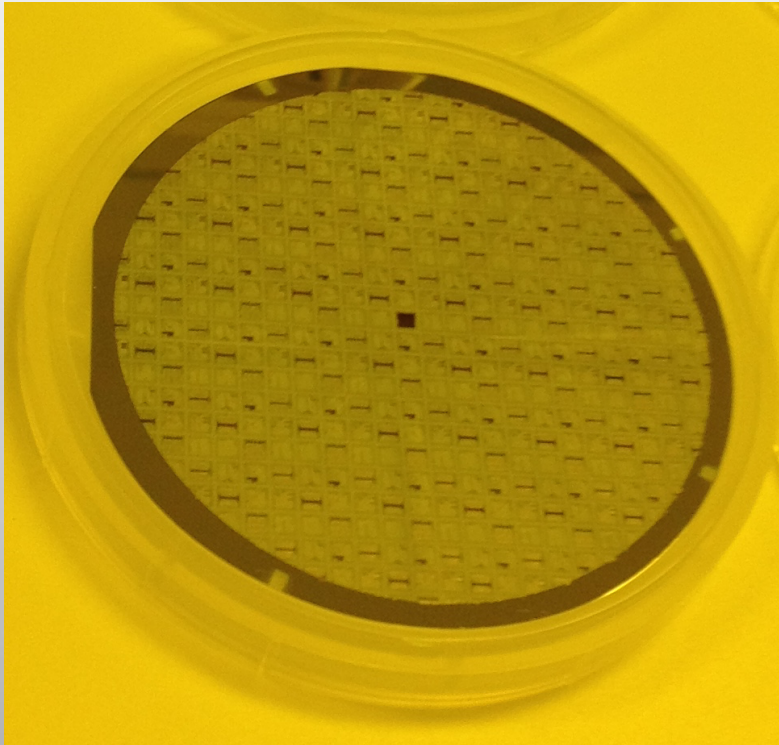


650 °C Ring Oscillator IC



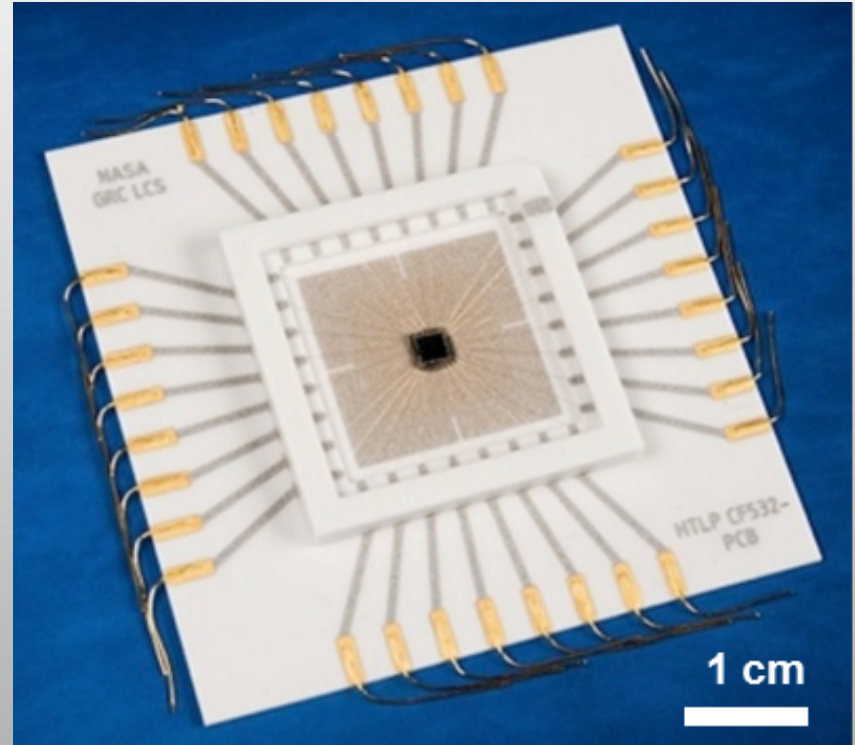
NASA Glenn Technology Advancement: 500 °C Durable SiC Integrated Circuits

76 mm Diameter SiC IC Wafer



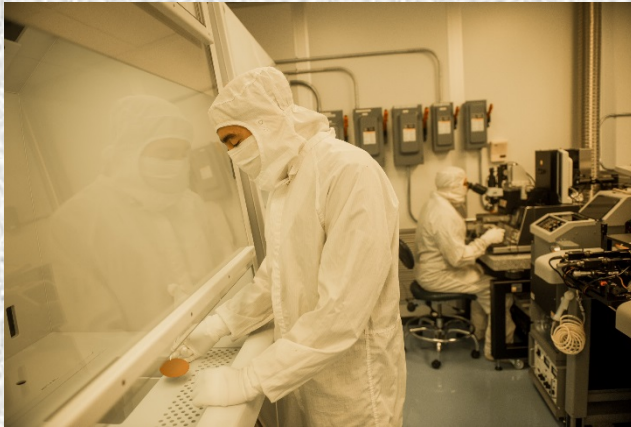
Each wafer yields 100's of
3 mm x 3 mm chips

High-T Packaged IC Chip



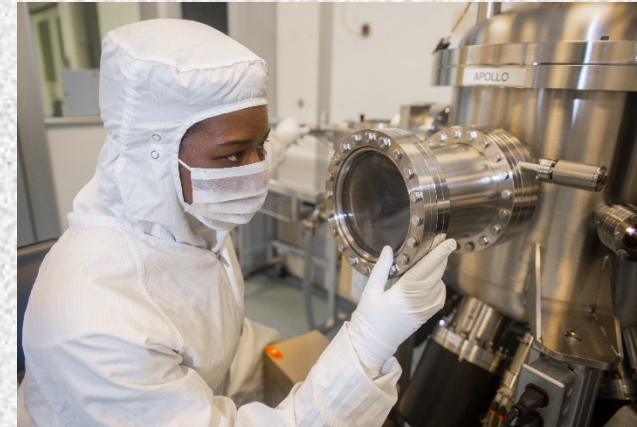
Each chip has 32 electrical
input/output connections

500 °C enabling IC design, fabrication, and packaging by NASA Glenn.

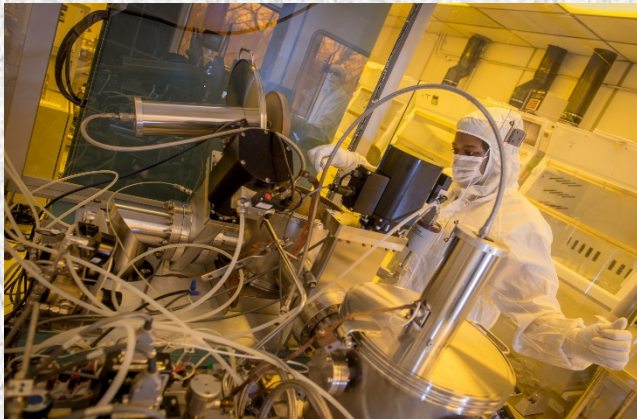


Wet Chemical Work Stations
and Mask Aligner

- 2500 square feet class 100 and 1000 cleanroom.
- Supports microfabrication of harsh environment sensors and integrated circuits on SiC wafers up to 100 mm diameter.



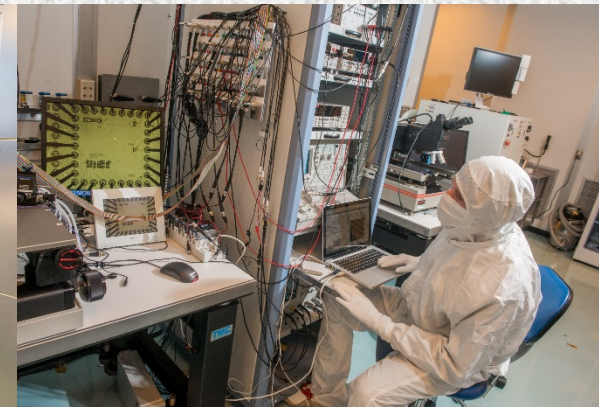
Ultra High Vacuum Metal
Deposition System



Reactive Ion Etcher



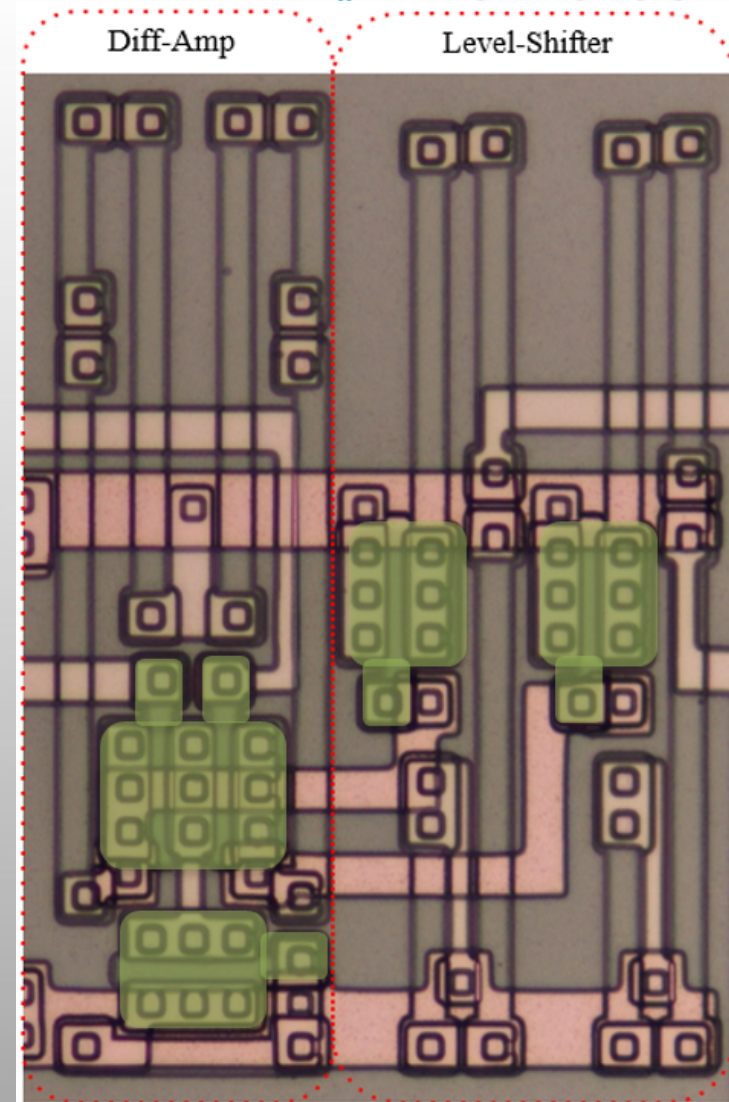
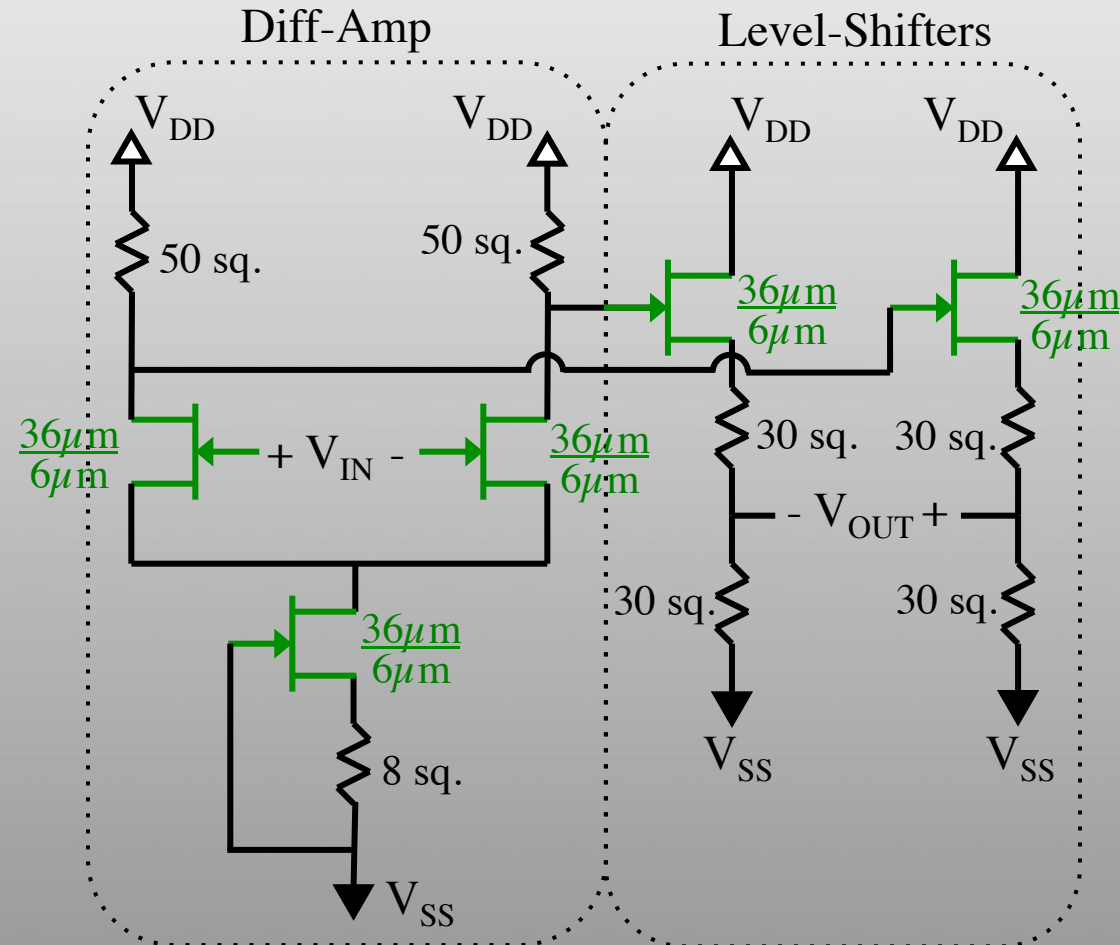
Oxidation and Annealing
Furnaces and Silicon Dioxide
Low Pressure Chemical Vapor
Deposition System



Probe Test Station

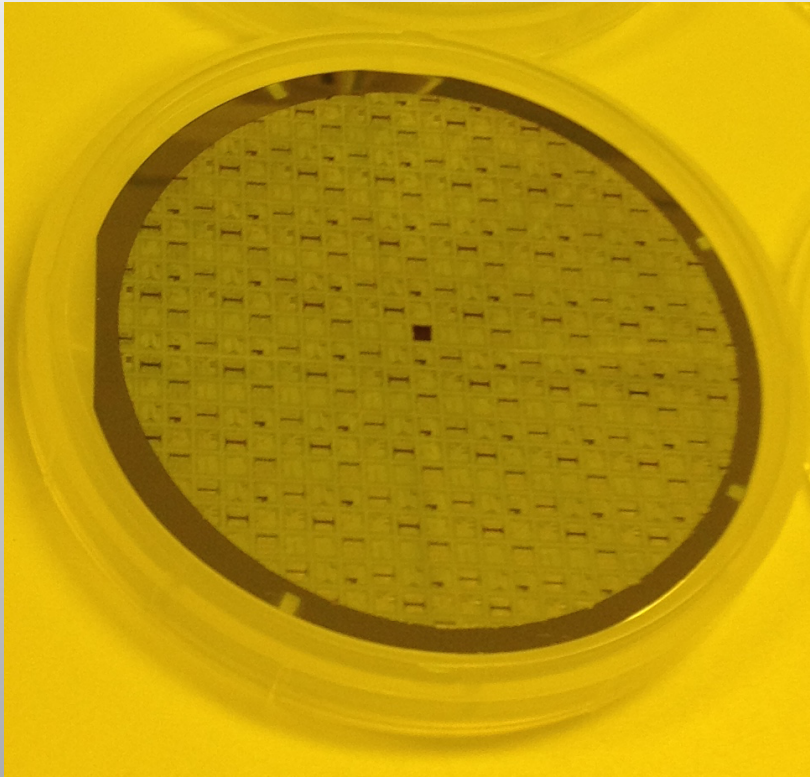
SiC JFET Integrated Circuit Design

All integrated circuits of this work are comprised of interconnected 4H-SiC **n-JFET's** and 4H-SiC n-resistors.



Circuits work from room temperature to 500 °C

Partnership Opportunity: Prototyping of Extreme Environment ICs



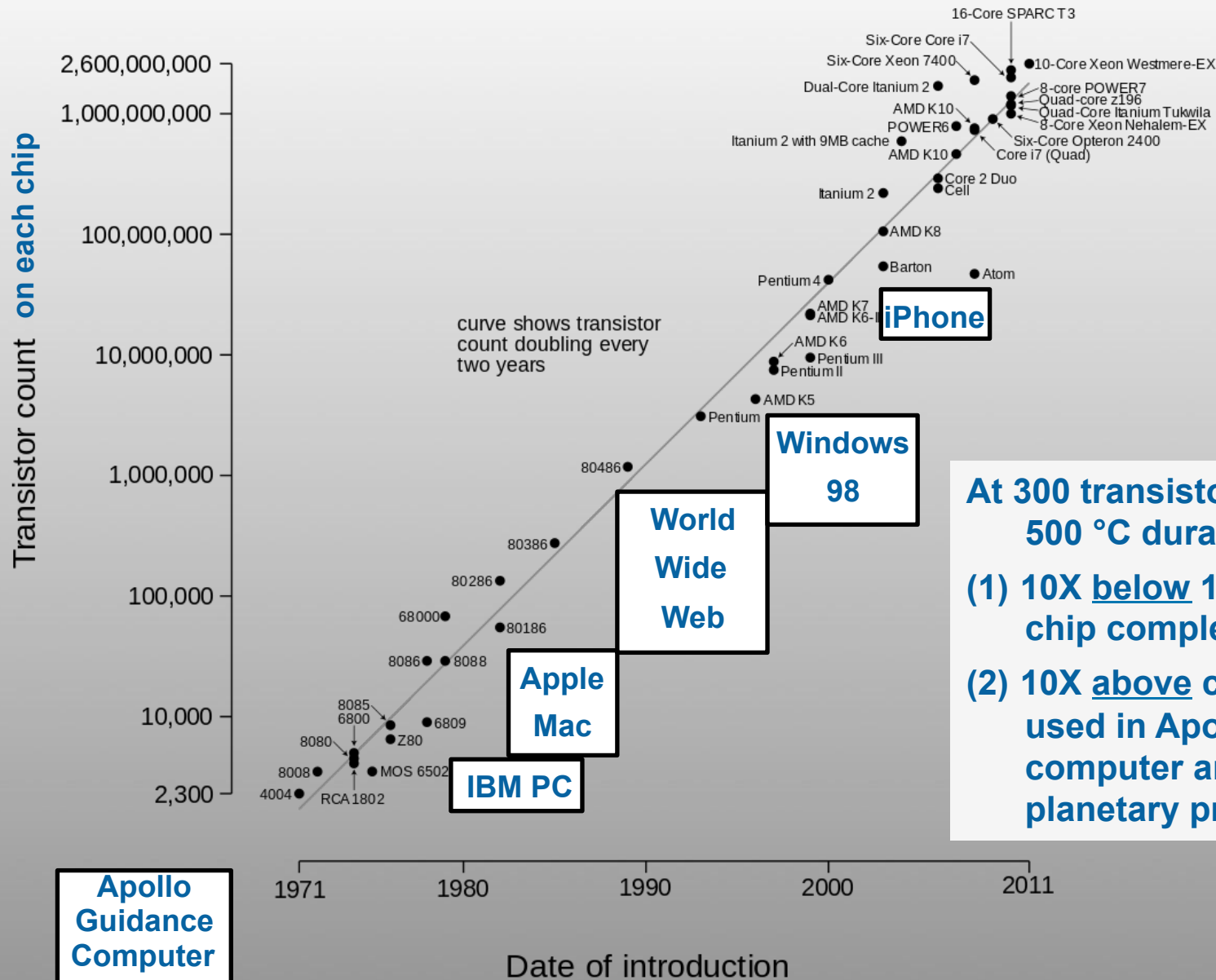
Circuit design guide online at
<https://sic.grc.nasa.gov>

**Additional wafer fabrication runs
will continue to advance 500 °C
durable IC technology.**

**On each wafer there will be room
to implement custom chips with
circuit designs from outside
partners wishing to explore this
emerging capability.**

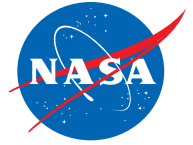
**Must meet NASA SiC JFET IC
design constraints, including:
Less than 300 transistors/chip
Negative signal voltages.**

(Graph By Wgsimon - Own work, CC BY-SA 3.0, <https://commons.wikimedia.org/w/index.php?curid=5161625>)



At 300 transistors, NASA
500 °C durable ICs are:

- (1) 10X below 1971 silicon chip complexity.
- (2) 10X above chip complexity used in Apollo guidance computer and initial planetary probes.



Testing Division Test Facility Overview

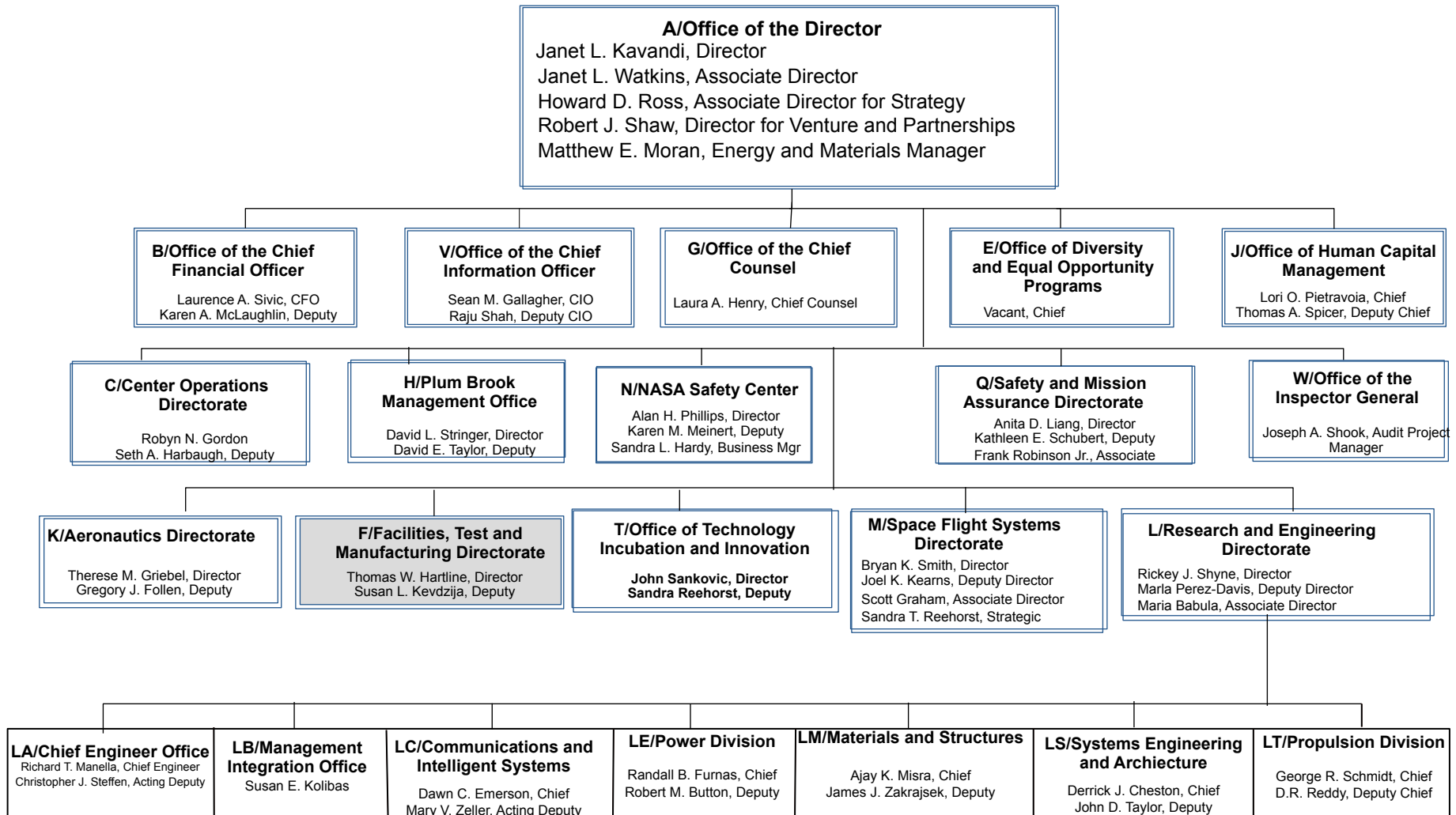
Linda Elonen-Wright



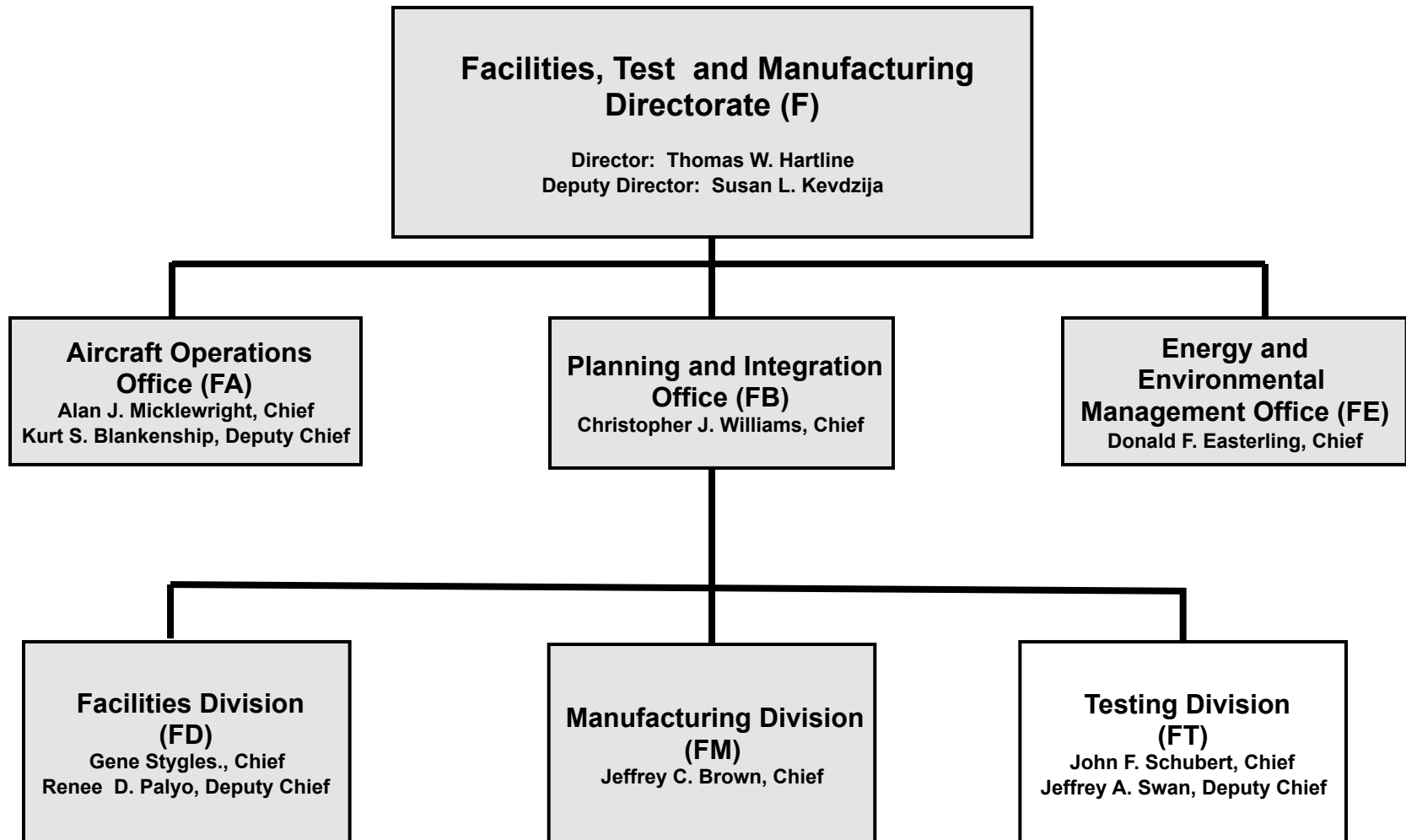
Welcome to the Glenn Research Center



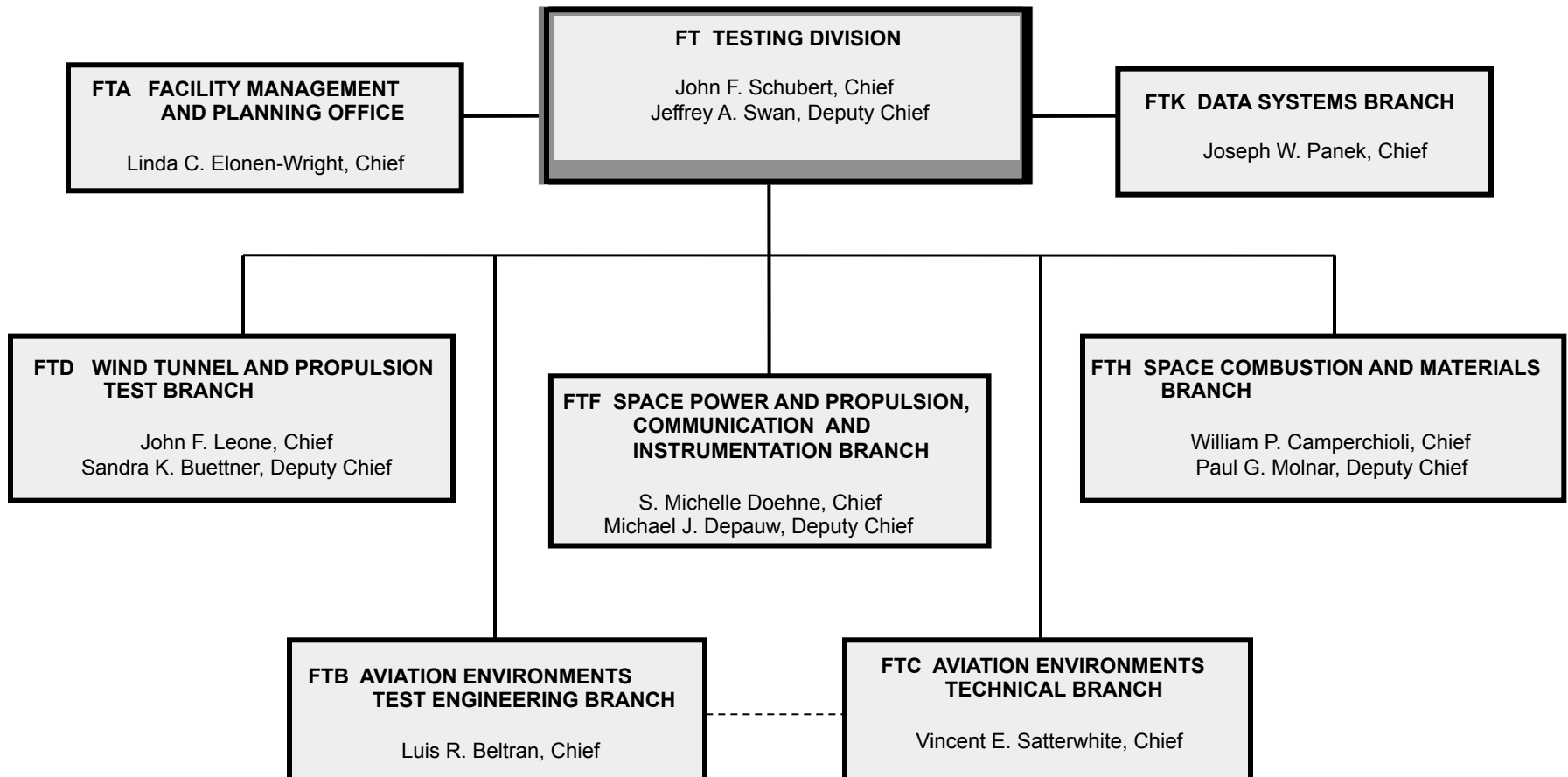
Glenn Research Center



FACILITIES, TEST AND MANUFACTURING DIRECTORATE (CODE F)



TESTING DIVISION (CODE FT)



NASA Glenn Research Center at Lewis Field



- Established in 1941 by National Advisory Committee for Aeronautics (NACA) as the NACA Aircraft Engine Research Laboratory
- With the formation of NASA in 1958, it was renamed as the Lewis Research Center to honor George W. Lewis
- In March 1999, it was officially renamed as the NASA John H. Glenn Research Center at Lewis Field to recognize the contributions of two outstanding men, John H. Glenn and George W. Lewis

NASA John H. Glenn Research Center

NASA Glenn's main campus, in Cleveland, Ohio, includes world-class research facilities supporting aeronautics, aerospace and space program areas on a 350 acre site containing 150 buildings.

NASA Glenn also incorporates the 6400-acre Plum Brook field station near Sandusky, Ohio. Plum Brook Station is the home of four world-class test facilities, specializing in very large-scale tests which would be hazardous within the confines of the main campus.

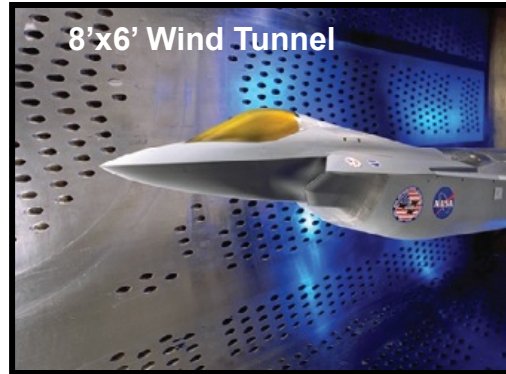


NASA GRC Unique Aero Test Facilities



Subsonic Propulsion Wind Tunnels

- Noise suppression
- Inlet/Airframe integration
- STOVL hot gas ingestion



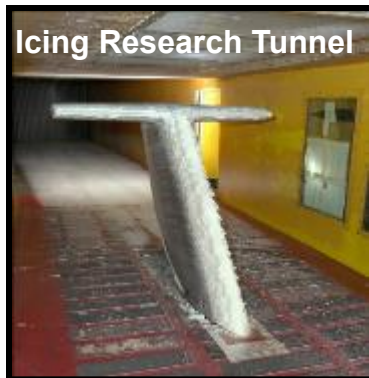
Transonic and Supersonic Propulsion Wind Tunnels

- Advanced propulsion concepts
- Inlet/Airframe Integration
- Internal/external aerodynamics



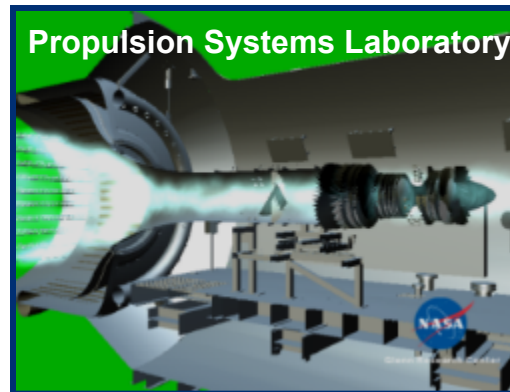
Engine Acoustic Research Facility

- Fan/nozzle acoustics research
- Simulate hot engine nozzles in flight
- Aerodynamic and Aeroacoustic measurements capabilities



Largest Icing Tunnel in US

- Aircraft icing certification
- Ice protection systems development
- Icing prediction/code validation



NASA's only altitude full-scale engine facility

- Jet Engine Icing Research
- Engine operability/performance
- Nozzle-engine integration/development

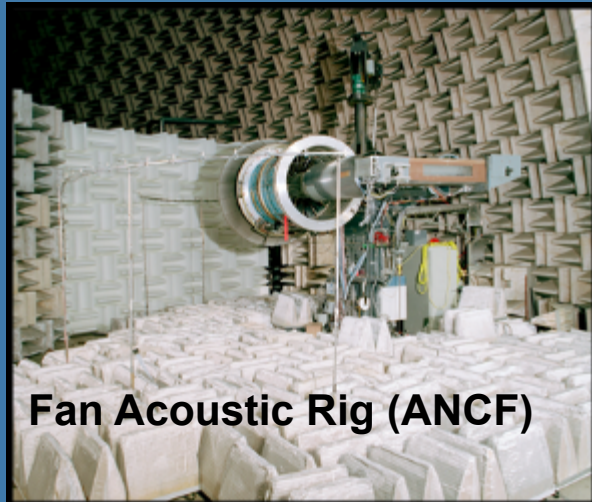


Over 50 Versatile Engine Component Facilities

- Combustor and Heat Transfer
- Compressor and Turbine
- Inlets and Nozzles

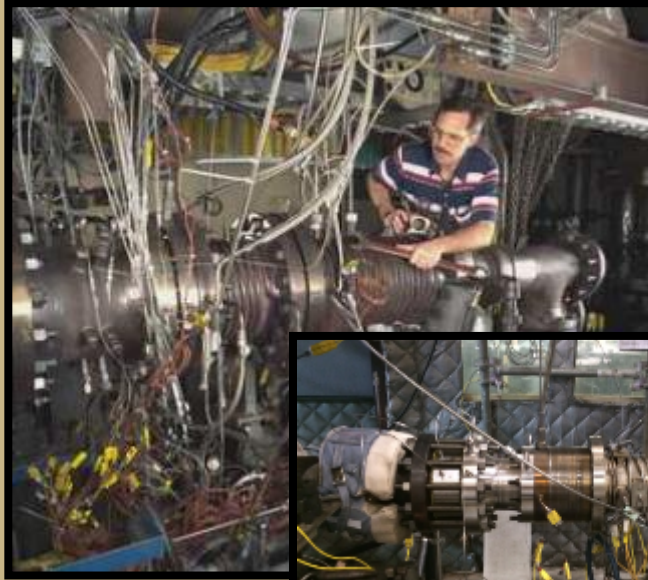
Aero-Acoustic Propulsion Lab (AAPL)

Nozzle/Fan Acoustic Test Rigs



- Acoustic Dome Built in early 1990's to support Nozzle Noise Reduction Research:
 - Nozzle Acoustic Test Rig (NATR): Free Jet Acoustic Tunnel (Mach 0.30, 4 Ft Diameter); microphone array outside tunnel flow), Jet Exit Rig simulates engine exit conditions.
 - Advanced Noise Control Fan (ANCF): Built in 1995 for low TRL fundamental research (4 ft dia. fan, 2200 RPMs).
 - Small Hot Acoustic Jet Rig (SHAJR): Built in 2000 for low TRL nozzle research (no flight flow). About 1/10th cost of NATR, so Acoustic Branch uses to screen nozzle concepts to test in NATR.
- First FT facility fully contracted in FY03, all TFOME Engineering and Technician Staff.

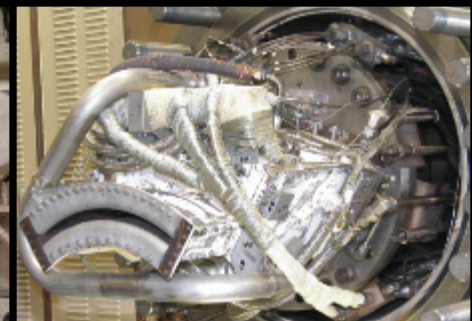
Engine Research Building (ERB) Combustor Facilities



CE-5B Stand 1, LDI Concept Supersonic Combustor tested in Stand 2



ASCR with New Plenum (replaced in 2012)



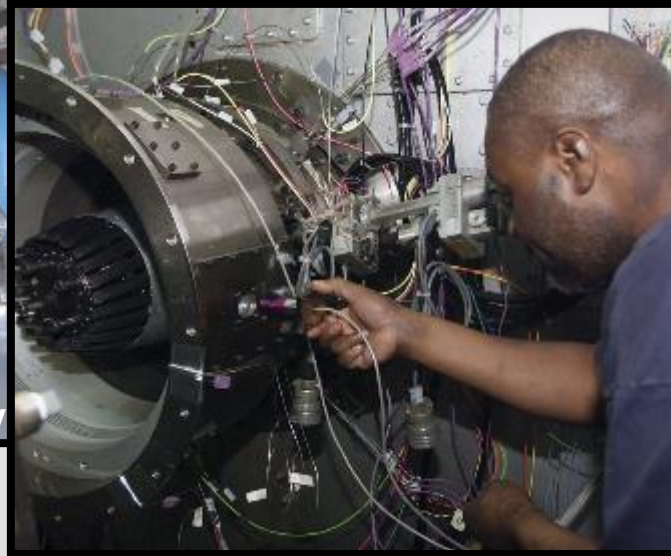
GE Sector Tests (not current ERA concepts)

- Combustor area busiest in ERB; ASCR, CE-5B, CE-13, SE-5, SE-11, CE-9.
 - ASCR was built in 1995 to support higher pressure combustor testing, twice pressure of other NASA GRC combustor facilities (900 PSIG, 1300 F inlet and 50 lb/sec air flow)
 - CE-5B most utilized combustor facility (450 PSIG, 1350 F and 10 lb/sec air flow)
 - ERA customer supporting all ASCR/CE-5B tests in FY14 and FY15 (about staff of 16)
- Smaller cells support lower TRL work, customer facilities supported by AeroSciences, High Speed and Fixed Wing.

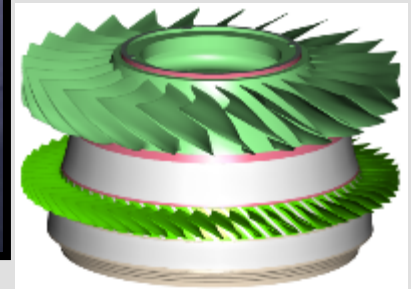
Engine Research Building (ERB) Turbo-Machinery Facilities



**CE-18 Centrifugal
Compressor Test Facility**

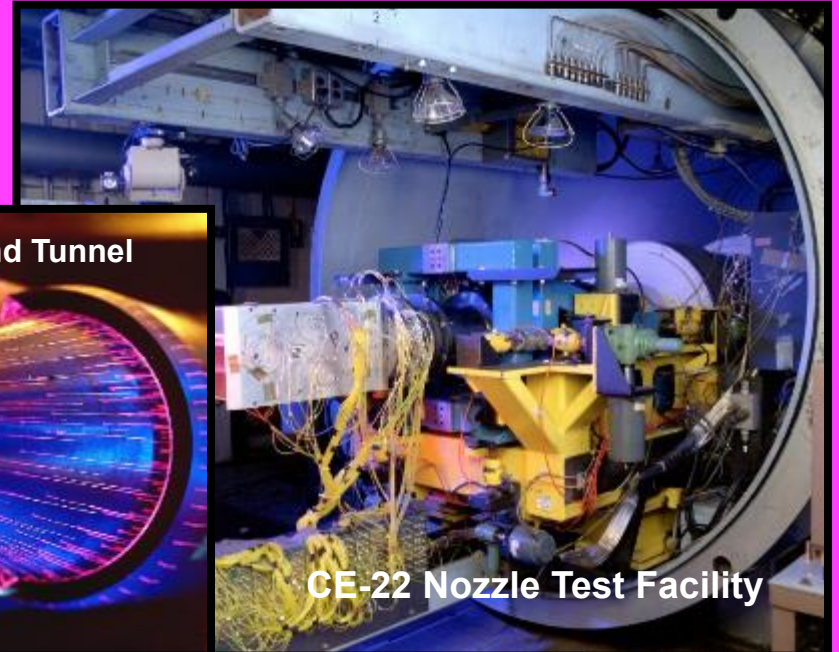
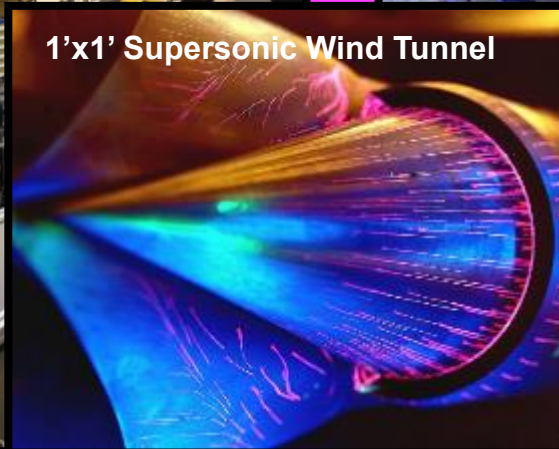
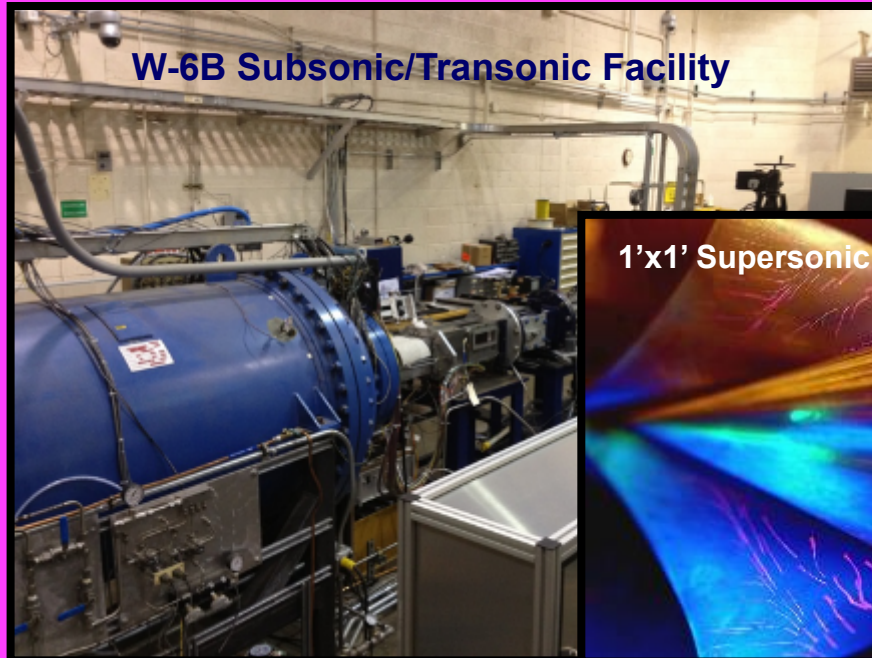


**W-7/8 Compressor
Test Facilities**



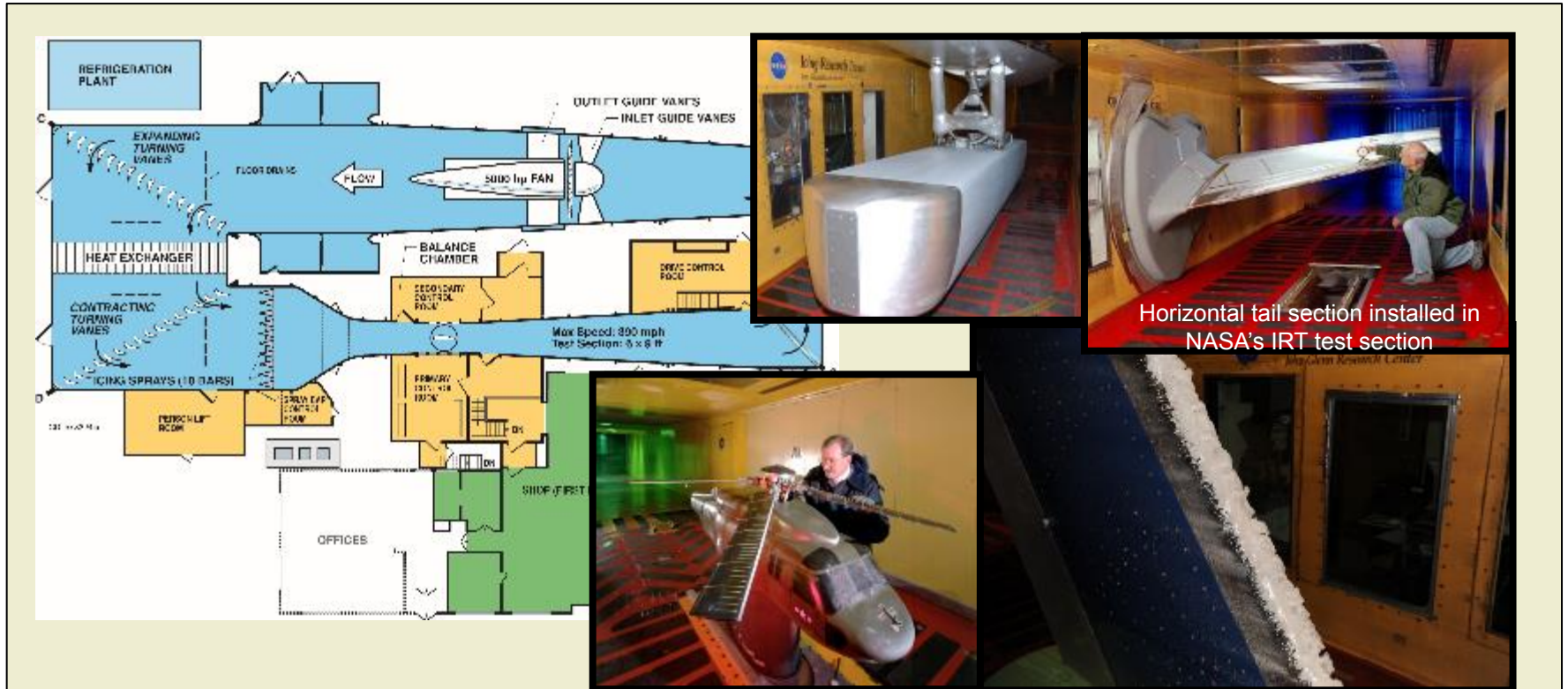
- Second busiest area in ERB, active facilities:
 - W-7 (Multi-stage compressor facility)
 - CE-18 (Centrifugal compressors)
 - CW-22 (Turbine Blade Cascade)
- Single Spool Turbine Facility (W-6A) placed in stand-by in FY13, Center FY14 funding provided to complete drive-line system (new torque-meter, drive shafts, couplings).
 - FY15 discussions for reimbursable work to complete facility (still TBD)
- FY16+ facilities utilization after ERA will depend on reimbursables

ERB Flow Physics Facilities



- Flow Physics Main facilities (Less utilized than other areas):
 - 1'x1' Supersonic Wind Tunnel (test up to Mach 6.0)
 - CE-22 Nozzle Test Facility (simulate altitude nozzle thrust performance)
 - W-6B (used more because 1'x1' more expensive to operate)
 - Also many Small Mechanical Components and R&D Labs
- 1'x1' SWT and CE-22 both reactivated in FY13 to support customer tests in FY14.
- Main Customers: High Speed, AeroSciences, Fixed Wing and reimbursables.

Icing Research Tunnel

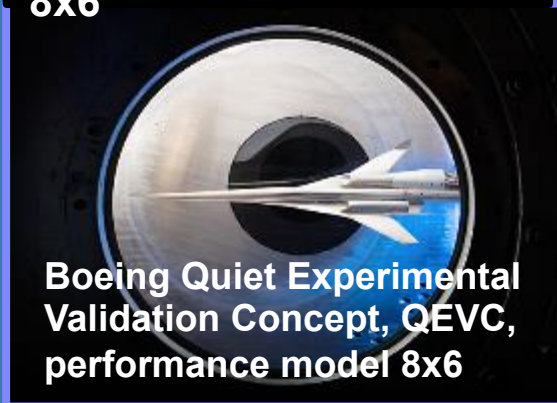


- NASA GRC's busiest facility; current occupancy through December 2015.
- Provides FAA certification of ice protection systems for military and commercial aircraft
 - 6' x 9' Ft Test Section, Speed Range 50–325 knots, Temp. = -35C
- Completed major Icing Calibration (November - February) and back to customer testing in March 2014.
- Fully TFOME contracted in January 2013; current staff 7 engineers and 9 technicians.

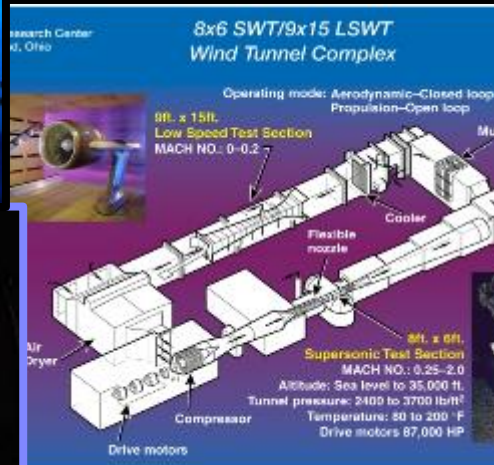
8x6 SWT/9x15 LSWT



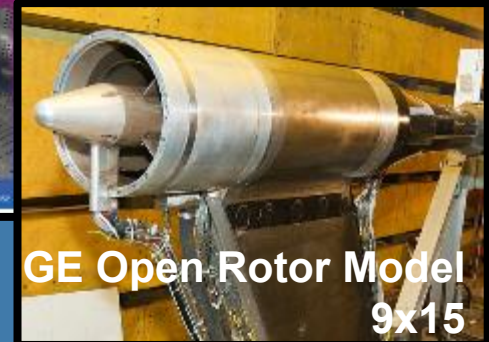
**GE Open Rotor Model
8x6**



**Boeing Quiet Experimental
Validation Concept, QEVC,
performance model 8x6**



P&W GTF Model 9x15



**GE Open Rotor Model
9x15**

- The 8x6 provides subsonic, transonic and supersonic speed range. It operates either in an aerodynamic closed-loop cycle, testing aerodynamic performance models, or in a propulsion open-loop cycle that tests live fuel burning engines and models.
- The 9x15 specializes in evaluating aerodynamic performance and acoustic characteristics of fans, nozzles, inlets, propellers, and hot gas-ingestion of advanced Short Takeoff Vertical Landing (STOVL) systems.

10x10 SWT



Combined Cycle Engine, CCE



RATTLRS



Revolutionary Approach To Time-critical
Long Range Strike



MSL Flexible Canopy Test

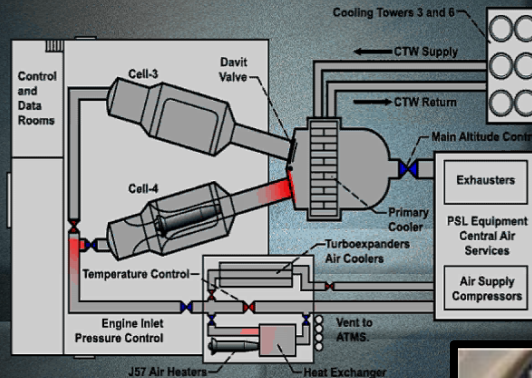


Advanced Inflatable
Decelerator for
Atmospheric Reentry

- The test section can accommodate large-scale models, full-scale engines and aircraft components. The 10x10 was specifically designed to test supersonic propulsion components such as inlets and nozzles, propulsion system integration, and full-scale jet and rocket engines. It can operate as a closed-loop system (aerodynamic cycle) or open-loop system (propulsion cycle), reaching test section speeds of Mach 2.0 to 3.5 and very low speeds from 0 to Mach 0.36. Gust and Mach plates are sometimes installed to expand local Mach number conditions between Mach 1.5 and 4.1.

Propulsion Systems Laboratory (PSL)

Pratt & Whitney F100



Williams FJ-33



Icing System Spray Bars

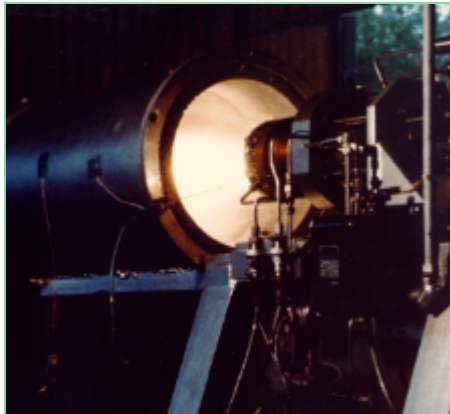


**Honeywell ALF502
Engine Icing Test**



- The PSL is NASA's only ground-based test facility that can provide true flight simulation for experimental research on air-breathing propulsion systems. Altitudes to 90,000 feet and Mach numbers to 3.0 in one cell and 6.0 in the other can be simulated continuously. An icing system was recently added to Cell 3 providing the capability to simulate clouds of ice crystals and liquid water droplets.

NASA GRC Unique Space Facilities



Combustion Research

Advanced Rocket Propulsion

Materials Research

Ignition Technology

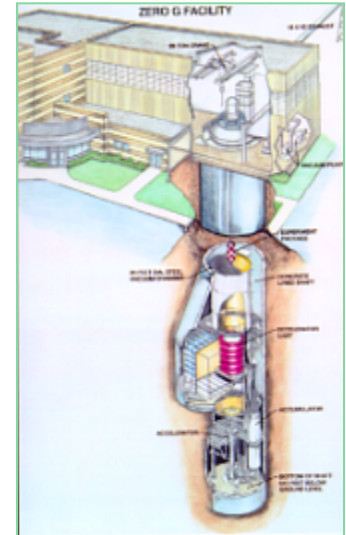
Diagnostics

Reduced Gravity

Combustion Science

Fluid Physics

Materials Research



Space Simulation

Advanced Electric Propulsion

Space Power

Energy Storage

Integrated Power/Propulsion Systems

Cryogenic Fluid Management

Cryogenic Insulation

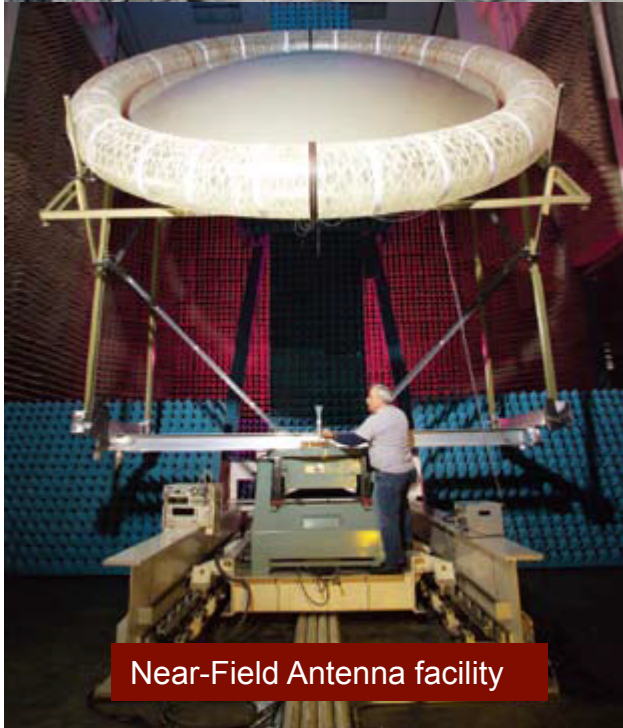
Cryogenic Propellant Systems

Low-Gravity Cryogenic Gauging

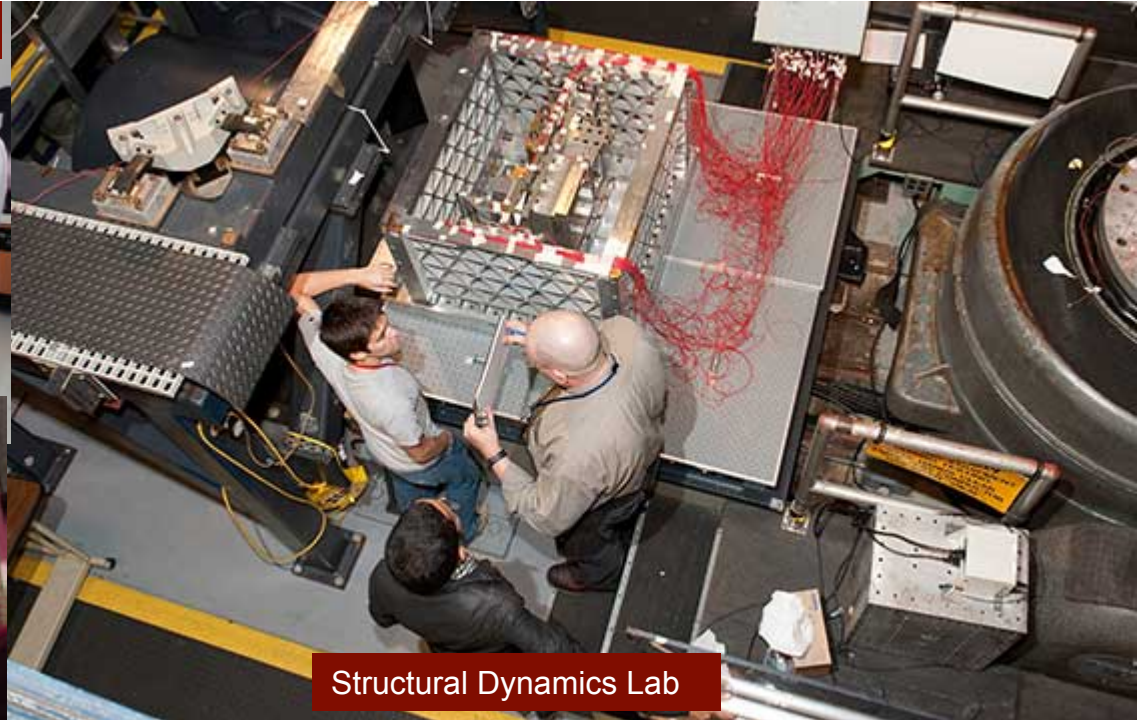


Communications and Instrumentation

Class 100 Clean room; SiC ion etching



Near-Field Antenna facility



Structural Dynamics Lab

- The Communication labs and facilities support a variety of component and end-to-end system and network testing.
- Instrumentation and Controls testing includes development of harsh environment sensors, high-temp/high-power electronics, and high data-rate optical instrumentation.
- Structural Dynamics Laboratory verifies hardware survivability when exposed to vibration simulation.

Space Simulation Facilities



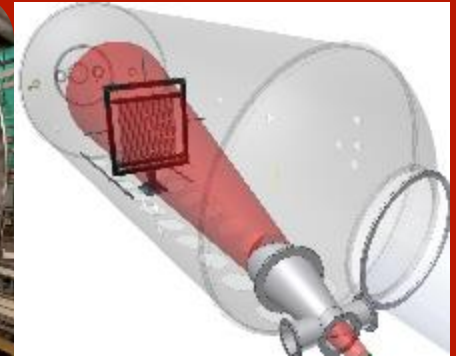
The space simulation facilities support research in the areas of electric propulsion, spacecraft power and space environmental effects at all phases of development. Applications include thermal vacuum testing of flight experiments, spacecraft hardware development, plasma interaction effects on spacecraft hardware and materials. There are two large, world-class chambers (VF-5: 15' diameter by 60' long, and VF-6: 25' diameter by 70' long), eight medium chambers, 7' to 10' in diameter by 20' to 30' long, 8 small chambers, 3' to 5' in diameter by 10' to 15' long and there are several bell jar vacuum facilities.

Space Power Facilities

Electrical Power Systems Test Bed



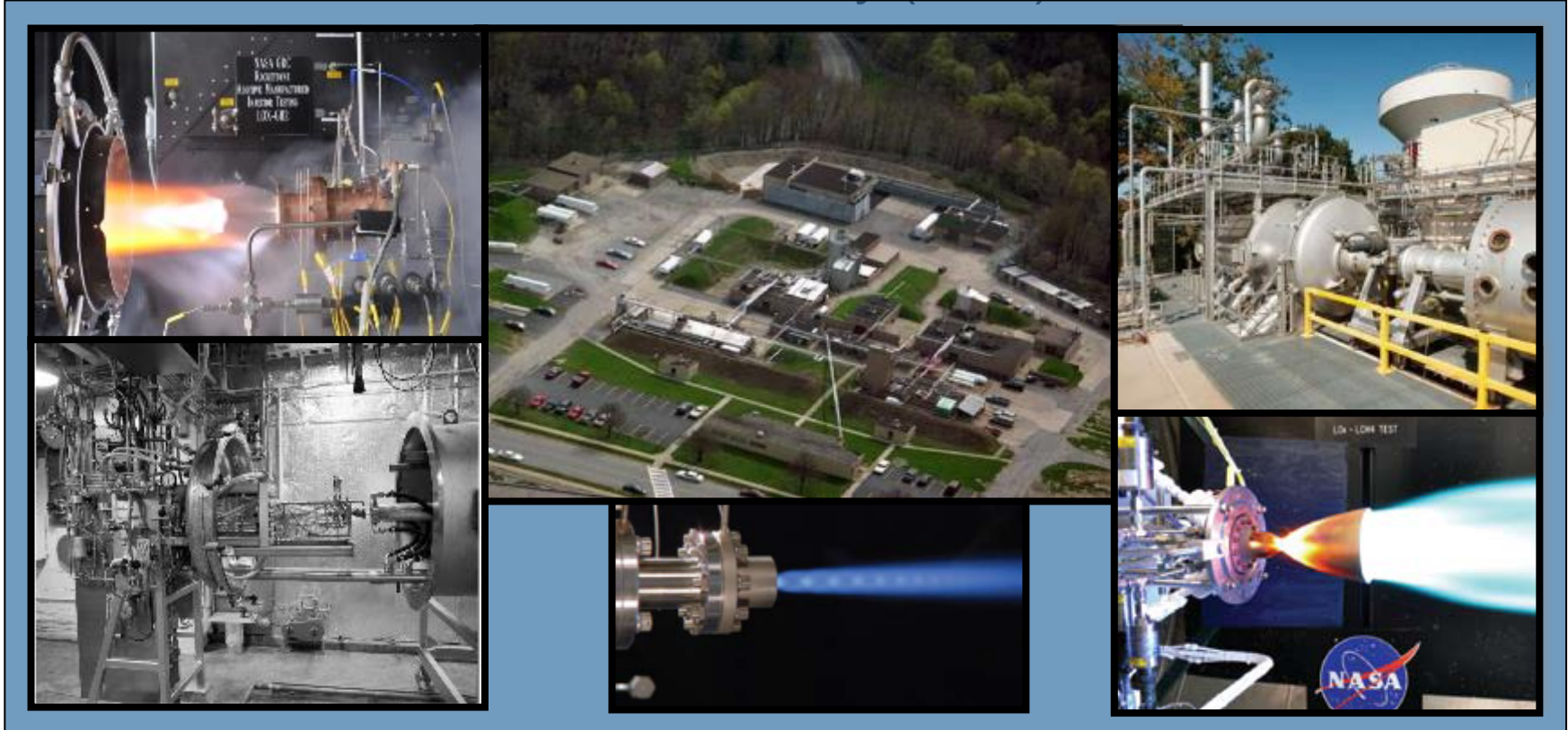
Thrust Vector Control Lab; Bldg. 333



DARPA FAST Testing in VF6

The space power facilities supports the design, development, assembly and testing of space power components and systems for the International Space Station, satellites, next generation launch vehicles and space based power systems. There are numerous testbeds that verify critical concepts, test prototype hardware and software, and validate systems in real-time simulations under actual loading and operating conditions. Testing capabilities include flywheel systems and components, battery systems, fuel cells, AC power sources, electrical actuators and power management and distribution hardware and software.

Research Combustion Laboratory (RCL)



- RCL is a complex of multiple test cells which supports chemical propulsion and materials testing
 - Green Propellant Infusion Mission (GPIM) – Cell 11
 - Additive Manufactured Component testing – Cell 32
 - Wave Bearing Rig – Cell 24A
- Altitude Combustion Stand (ACS)
 - Altitude testing with cryogenic conditioned propellants up to 2000 lb thrust

Alternative Fuels Laboratory

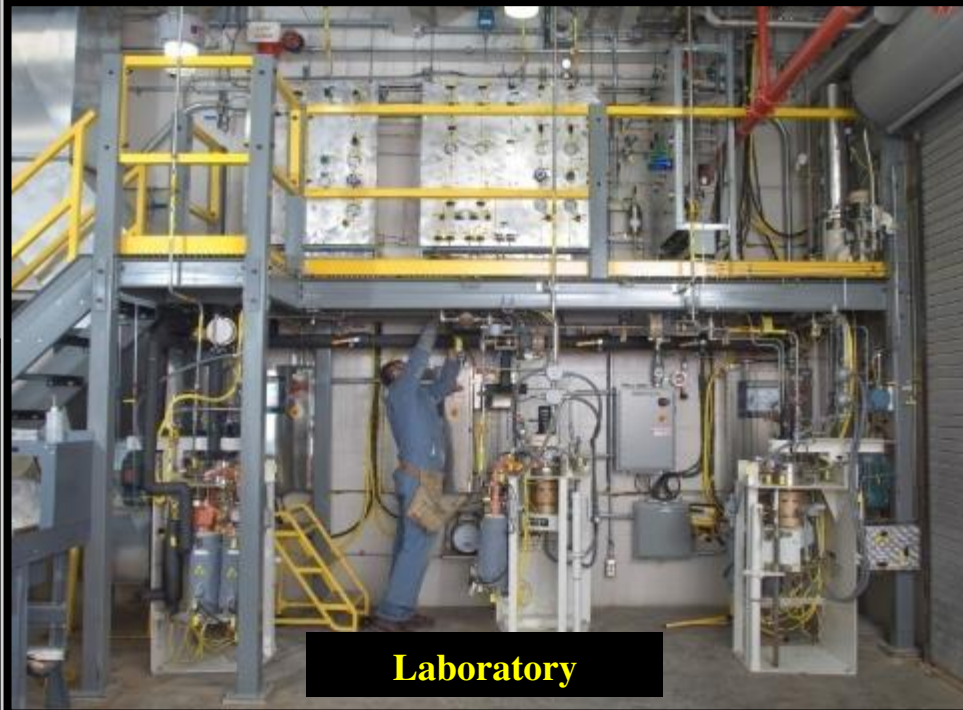
Control Room



Gas Chromatographs



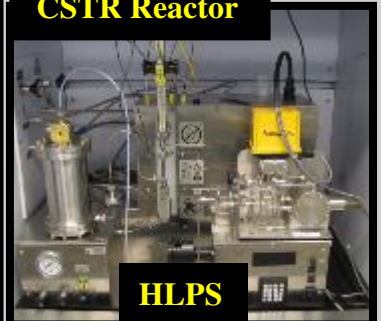
Laboratory



CSTR Reactor

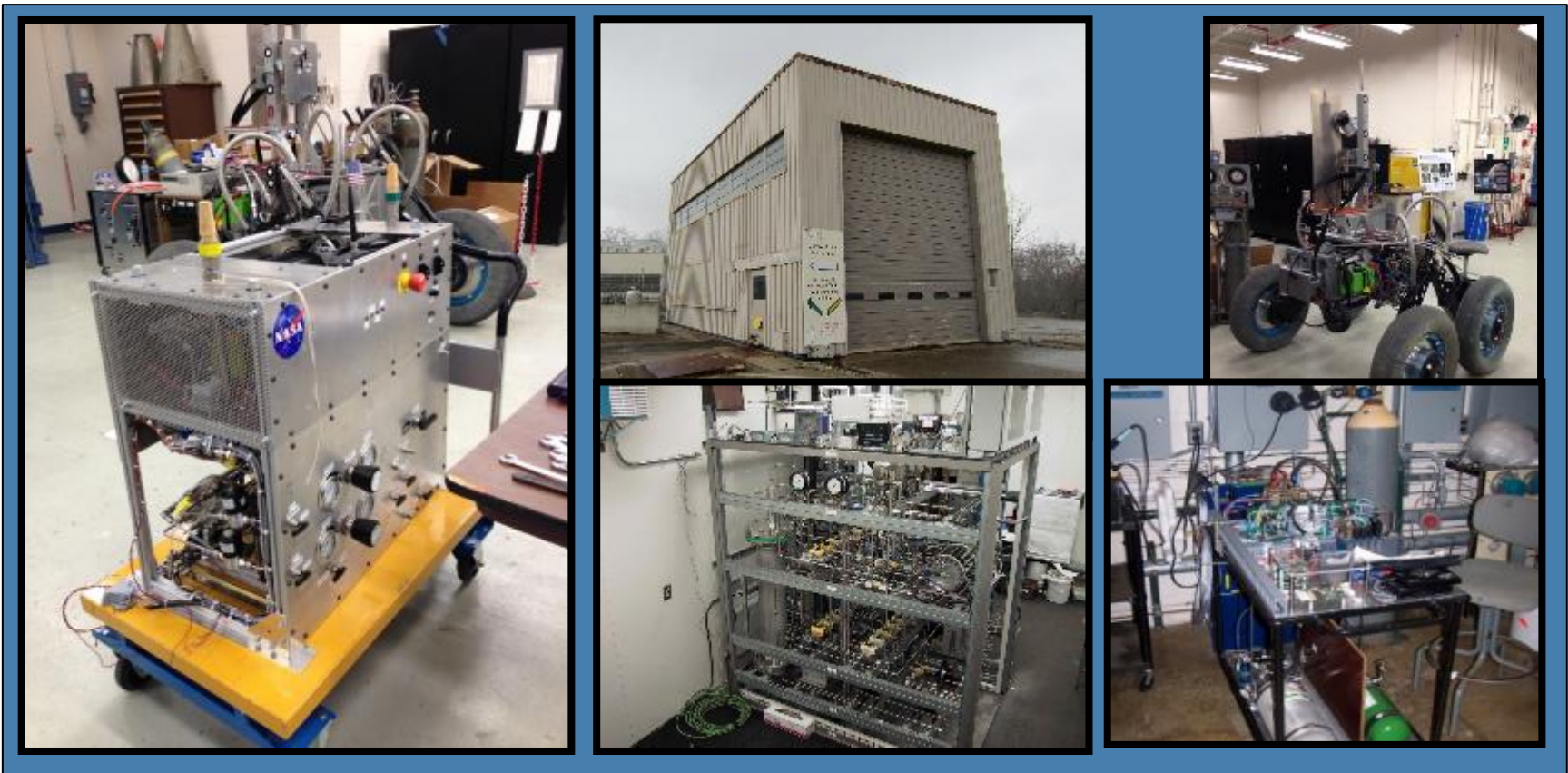


HLPS



- Complete research facility consisting of 3 Fischer-Tropsch (F-T) reactors and a comprehensive mini characterization laboratory with Gas Chromatographs and Hot Liquid Processing Simulator
- F-T synthesis converts catalyst into synthetic jet fuel
 - Improve F-T process through new catalyst development
 - Goal is to produce a cleaner and more economical alternative to traditional commercial jet fuel through reducing energy input and CO₂ emissions and increasing product yields

Fuel Cells



- Building 135 – Regenerative Fuel Cell Facility - Closed loop system test bed capable of simulating day/night power cycles, building on FY16 demo list
- Building 35 – RCL Test Cell 24C - Used to test small developmental fuel cell stacks
- Building 334 – Fuel Cell Laboratory - Future of fuel cell testing at GRC, 3 test cells, building supplied hydrogen, oxygen and nitrogen

Building 334 Fuel Cells Laboratory



- Glenn Extreme Environments Rig (GEER) – Cell 109 - Capable of simulating extreme environments such as Venus, 1450 PSIA, 932 deg F, specialty gasses. Scheduled to be operational fourth quarter, 2014
- Advanced Energy Conversion – Cell 110 - Attended and unattended operation of Parr reactor and calorimeter
- Fuel Cells Testing – Cell 111 - Future fuel cell testing will be performed in this facility



Creek Road Cryogenic Complex (CRCC)



- SMiRF (Small Multipurpose Research Facility) - Test facility specializing in ground testing for cryogenic storage, transfer, and gauging technologies.
- CCL-7 (Cryogenic Components Lab) - Smaller, versatile facility similar to SMiRF, used primarily for component level testing.
- CRCC Main Shop Building - Hardware and instrumentation buildup, Multi-Layer Insulation (MLI) Fabrication, and Clean Room.

Microgravity Facilities



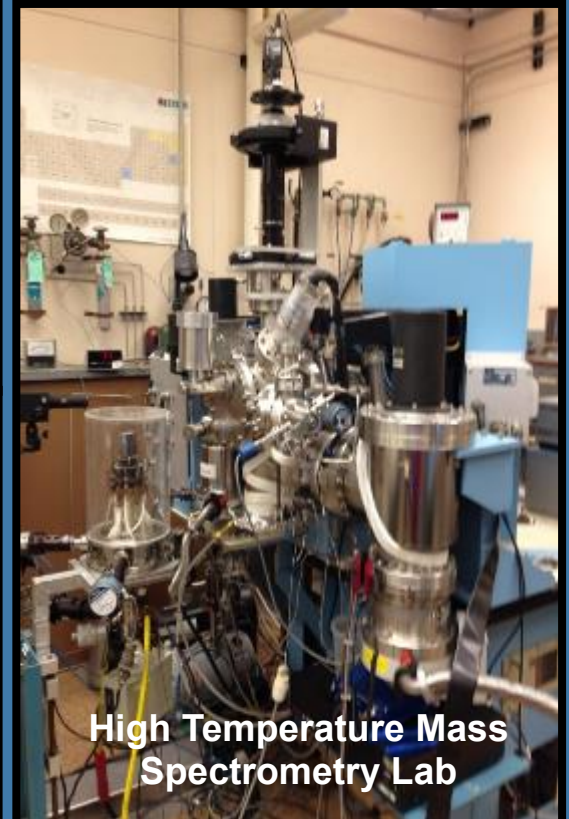
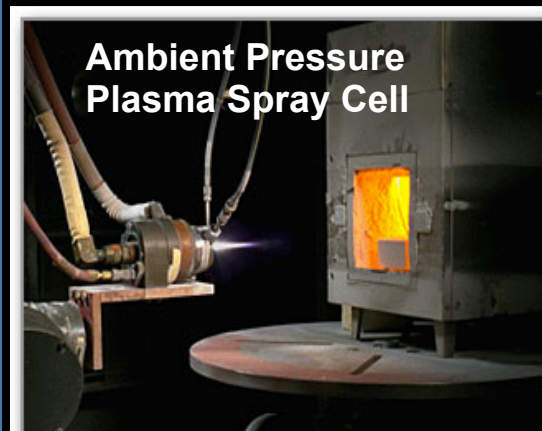
- Zero Gravity Research Facility
 - NASA's premier facility for ground based microgravity research
 - The largest facility of its kind in the World
 - 433 ft free fall provides 5.18s of microgravity
- 2.2 second Drop Tower
 - Compliments the Zero G Facility by providing a low cost, quick turn around microgravity test capability
 - 80' free fall provides 2.18 seconds of low gravity
- Support GRC reduced gravity aircraft experiments

Space Experiments Laboratory (SEL)



- Flight qualified electronics technicians have built hardware that has flown on over 50 missions aboard the ISS and Space Shuttle
- Technicians support electronics and mechanical build of breadboard, brass-board, engineering model, ground test, microgravity and flight experiments
- Currently supporting:
 - Spacecraft Fire Safety (SFS) flight hardware fabrication
 - Power Processing Unit (PPU) build
 - Flow Boiling Condensation Experiment (FBCE)

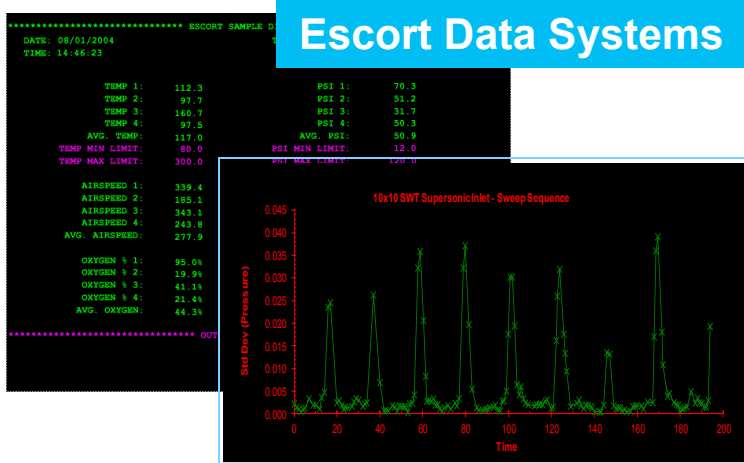
Materials Labs



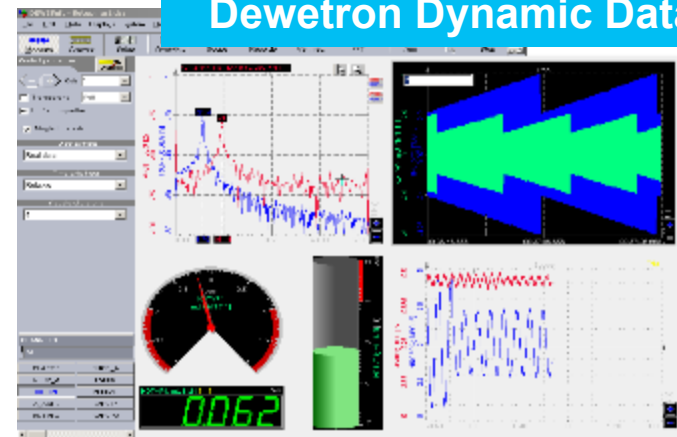
- Provide Engineering and Technician support to multiple materials labs/facilities
 - Labs located in buildings 24, 34, 49, 51, 105, and 106
- Supports research/testing for Structures and Materials Division (former RX)
- Highly specialized specimen machine shop
 - Experienced in machining exotic materials to precision standards

Data Systems – Product Lines

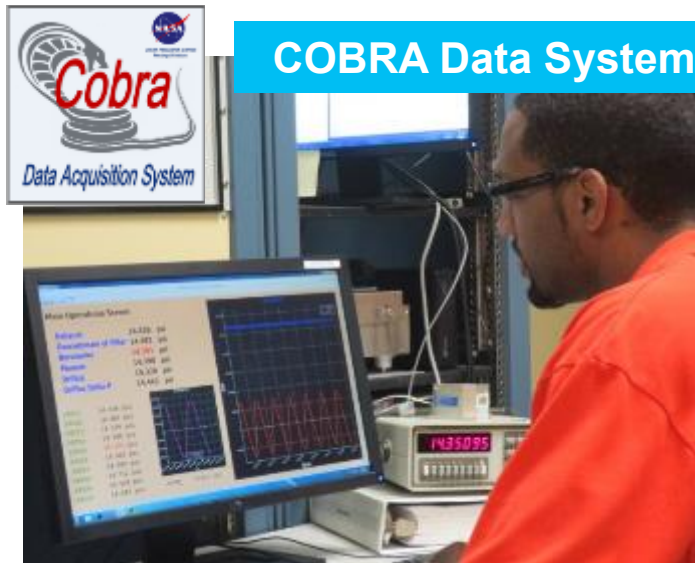
Escort Data Systems



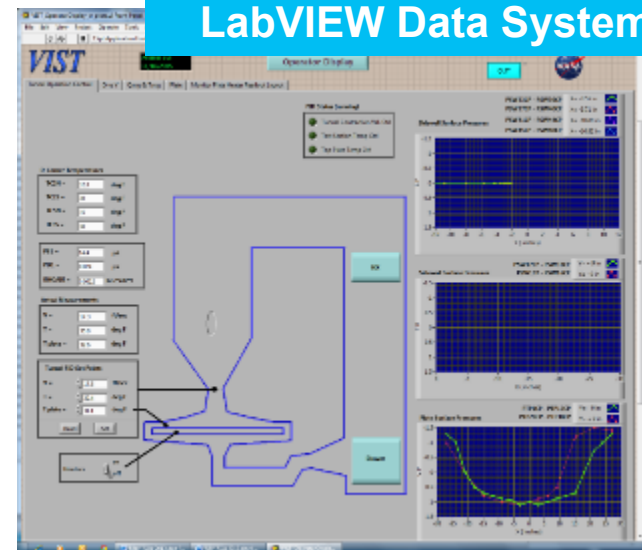
Dewetron Dynamic Data



COBRA Data Systems



LabVIEW Data Systems



Escort – Steady State Conditions, 1000s of channels **LabVIEW** – Tailored to facility, Couple hundred channels
Dewetron – Dynamic 8 to 64 channels **COBRA** – Escort replacement with added capabilities

NASA GRC-Plum Brook Station Unique Test Facilities

Propulsion Test

Liquid Engine/Stage Testing
Thermal-Vacuum
Cold-soak Start / Restart
Altitude Hot-fire



Space Simulation

Thermal-Vacuum (world's largest)
Reverberant Acoustic
Mechanical Vibration
Reverberant EMI/EMC

Cryogenic Testing

Cryogenic Component/Subsystem/System
Propellant Densification
Pressure Systems



NASA Glenn's Testing Information

Doing Business with NASA Glenn

NASA Glenn Research Center provides ground test facilities to industry, government, and academia specializing in:

- Acoustics
- Engine Components Testing
- Full-Scale Engine Testing
- Flight Research
- Icing Research
- Materials and Structures
- Microgravity
- Space Power and Propulsion
- Wind Tunnels

Our unique facilities offer superior customer service, flexible scheduling, and state-of-the-art testing capabilities.

NASA Glenn Test Facility Contact Information

Facility

Manager

Aero-Acoustics Propulsion Lab (acting)

Gwynn.A.Severt@nasa.gov
(216) 433-8310

10x10 SWT (acting)

James.W.Roeder@nasa.gov
(216) 433-5677

**Electric Propulsion Laboratory
Electric Propulsion Research Building**

Mary.J.Lobo@nasa.gov
(216) 433-8398

**Advanced Subsonic Combustion Rig
Engine Research Building
1x1 SWT**

Gwynn.A.Severt@nasa.gov
(216) 433-8310

Propulsion Systems Laboratory

Thomas.R.Hoffman@nasa.gov
(216) 433-5637

**Altitude Combustion Stand
Fuel Cell Test Laboratory
Heated Tube Facility
Research Combustion Laboratory
Small Multi-Purpose Research Facility
Materials Research and Development Lab**

Lori.A.Arnett@nasa.gov
(216) 433-2947

NASA Glenn Test Facility Contact Information

Facility	Manager
Icing Research Tunnel	John.R.Oldenburg@nasa.gov (216) 433-3583
8x6 SWT, 9x15 LSWT	David.E.Stark@nasa.gov (216) 433-2922
2.2 Second Drop Tower Zero-Gravity Research Facility	Eric.S.Neumann@nasa.gov (216) 433-2608
Power Systems Facility	James.S.Zakany@nasa.gov (216) 433-5080
<u>Plum Brook Station:</u> Space Power Facility	Gerald.A.Carek@nasa.gov (419) 621-3219
Cryogenic Propellant Tank Facility (K-Site), Hypersonic Tunnel Facility, Spacecraft Propulsion Research Facility (B-2),	Gerald.M.Hill@nasa.gov (419) 621-3235

Test Request Process

1. Customer contacts the facility manager and/or submits a test request form. Test request forms are available at: <http://facilities.grc.nasa.gov>
2. Appropriate NASA Glenn personnel will review the test request and provide a detailed cost estimate.
3. A formal test agreement is prepared and signed by both parties
4. Pre-test meetings are held to discuss project and test requirements

For more information please visit:

<http://facilities.grc.nasa.gov>, or call (216) 433-5731.

Thank you for your interest in our facilities.

